Chapter 1: Background

Commercial Development of Space

The thrust to promote commercial development of space dates back to the Reagan administration, whose National Space Policy deemed space commerce to be one of the most important goals for the Nation (see Table 2 for a listing of milestones in space commercialization). In 1984 Congress amended the National Aeronautics and Space Administration Act of 1958 with the declaration that "the general welfare of the United States requires that the NASA Administration … seek and encourage to the maximum extent possible the fullest commercial use of space activities",[1] thus firmly committing NASA to promoting space commerce. In response to this directive NASA established the Centers for Commercial Development of Space (later renamed the Commercial Space Centers) and developed a headquarters office, the Office of Commercial Programs (Code C), to oversee all commercial activities ranging from technology transfer to commercial manufacturing in space.

During the 1980s, NASA policy tended to focus on opening up space access freely and inexpensively, and envisioned the shuttle, Space Station, and other space platforms for eventual product manufacturing in space. In fact, in 1984 McDonnell Douglas and Johnson & Johnson embarked on a program, Electrophoresis in Space (EOS), that they optimistically hoped would lead to commercial production of drugs in space by 1987.[3]

In 1986 the explosion of Space Shuttle Challenger tragically demonstrated the risks associated with space travel and space commerce. All Space Shuttle flights were grounded for two years and commercialization efforts slowed considerably as programs such as EOS were abandoned or reconfigured. President Reagan issued a directive in 1988 aimed at reinvigorating the space program and specifically the commercialization of space. As government funding for NASA waned throughout the 1990s, the push to infuse NASA with private sector funds and involvement grew. Unfortunately this effort was hampered by the closing of Code C, and the disbursement of its activities to several NASA divisions.

President Clinton's 1996 space directive[3] placed space activities in the mainstream of national economic policy, and the Commercial Space Act of 1998 was designed "to encourage the development of a commercial space industry in the United States" by allowing commercial re-entry of space vehicles and streamlining the procedures by which the private sector could participate in space commerce.[4] The Act defined a series of mechanisms and agreements by which companies could obtain space flight opportunities aimed at furthering commercial ventures. Upon its passage, Rep. Dave Weldon commented: "*Our nation's future in space depends a great deal on our ability to develop a viable, cost-competitive commercial market, and (the Commercial Space Act) will help us do this. It streamlines processes and encourages the development of private-sector initiatives in space.*"[5]

Today, NASA's overall effort to provide commercial space-based opportunities takes a number of forms, including Technology Transfers (spin-offs), Space Act Agreements, Cooperative Agreements, and Small Business Innovation Research grants. Small and large private corporations are involved in a variety of space-related commercial activities, including the development of space hardware, launch and support of unmanned space activity (such as satellite systems), conduct of scientific research, and the patent and leasing of NASA technologies.

Table 2:
Milestones in Space Commercialization

Date	Event	Significance for Space Commercialization
1982	President Reagan issues National Space Policy	The advent of space commercialization as NASA is directed to expand private sector involvement and investment in space.
1984	NASA issues Commercial Space Policy	Commercialization efforts are focused. A headquarters office, the Office of Commercial Programs (Code C), is opened to oversee all commercial activities. Centers for Commercial Development of Space (later renamed the Centers for Space Commercialization) are established.
1984	Congressional Space Act	A foundation for long-duration exploration, experimentation, and manufacturing in space is provided by this Act's charge to develop a permanently manned space station.
1984	Electrophoresis in Space (EOS) Program launched	Ambitious program to develop space manufacturing launched. NASA, McDonnell Douglas, and Johnson & Johnson propose to produce drugs in space within the next few years.
1986	Space Shuttle Challenger disaster	Dangers of space travel and the risk of space commerce tragically highlighted. Two-year suspension of Shuttle launches ensues. Emphasis on space manufacturing and commercialization slows.
1988	President Reagan issues Space Policy and Commercial Space Initiative	Commercialization of space becomes a major component of U.S. space policy.
1990s	Reduced NASA funding	Code C dismantled and commercialization efforts become fragmented as former Code C functions are distributed among various NASA divisions.
1991	President Bush issues U.S. Commercial Space Policy Guidelines	Expanded government initiatives to encourage space sector's growth including transfer of government-developed technology to the private sector.
1996	President Clinton issues National Space Policy	Space activities are propelled directly into the mainstream of national economic policy and international competitiveness issues. Detailed guidelines recognize the maturity of the industry proposals to develop commercial space systems, particularly satellite communications.
1998	Commercial Space Act	Commercial development of Earth orbital space set as priority goal for construction of International Space Station. Thirty percent of research opportunities on Station set aside for commercial endeavors.

Space Commercialization and the ISS

From the mid-1990s onward, space commercialization began to focus on the International Space Station. The Commercial Space Act of 1998 made the commercial development of space a priority goal behind construction of the International Space Station (ISS). In the Fall of 1998 NASA responded by releasing its Commercial Development Plan for the International Space Station[6], which identified a number of feasible business ventures. The goal was to position the agency so that an active economic development program would be in place by the time U.S. research facilities were on station in 2000.

NASA's plan for ISS commercialization envisions the stimulation of private sector investment and participation in the categories of *utilization*, *operations,* and *new capability development*. For utilization, the ISS was envisioned as an "orbiting laboratory that will provide an unprecedented facility for long-term scientific research, technology development, and the achievement of commercial goals in the environment of space".[7] Commercial and government users would have access to sophisticated laboratory facilities, including pressurized modules and those in the near vacuum of space, and resources such as power supplies, crew time, thermal control, telecommunications/teleoperations, gas supplies, and venting. To support commercial space activity, NASA set aside approximately 30% of the U.S. research facilities on station for commercial development.

Beyond these research opportunities, NASA also envisions commercialization of operations including mission planning, flight control, and delivery/return of crew and cargo. The goal is to ultimately privatize ISS operations so that NASA becomes one of many paying customers, rather than the primary provider and funding agency of ISS opportunities for the United States and its citizens. In a similar fashion, NASA seeks to foster new capabilities developments that meet the demands of public and private customers. These market-driven opportunities could include improving existing resources (such as power supplies or habitation modules) or developing new resources (such as modules for space tourism).

NASA's role in promoting space commerce is modeled after the role that the U.S. government has played in facilitating the development of other technological and physical frontiers. A good example is the development of the "Wild West", where government invested in developing transportation facilities and other infrastructure for commerce, offered incentives and support to businesses that came forward to participate in this development, and then gradually relinquished control to the market economy. When this model is applied to space commerce, NASA can be commended for successfully engaging the commercial sector in space exploration functions and supporting the creation of a thriving aerospace industry (with revenue perhaps exceeding $100 billion in 2000[8]). Aerospace companies, like railroad pioneers, initially participated as vendors with limited control or investment. Today the aerospace industry is mature enough to invite heavy private sector enterprises and investment, even though NASA remains its primary client.

The current opportunities aboard the Space Station add a new dimension to human endeavors in space by widening the range of industries that can be engaged in space commerce, and by changing the nature of this participation. ISS commercialization, and the Space Shuttle before it, has triggered three important shifts. *First*, commercialization has moved from primary commercial utilization by the aerospace and satellite communication industries to utilization by a broad number of industries engaged in a variety of activities. *Second*, it has advanced commercialization beyond technology transfer where NASA has very successfully arranged numerous applications of its innovations to profit-making products. In this way commercialization on the ISS plays an important role in progressing industry utilization from product development via spin-offs to direct development. *Finally*, it means that industry participation now involves users, and not merely contractors. In the long run, this will position industry to not only utilize the station but to operate it and inevitably enhance its capabilities.

Policies and Procedures

Commercial participation in ISS-based research can take one of two forms—an Entrepreneurial Offer (EO) or a collaborative effort with a Commercial Space Center (CSC). Entrepreneurial Offers are structured as the means by which private investments can be made to develop new, commercial markets without the benefit of government funds.[7] Such offers can be in the areas of utilization, operations, or new capabilities development. An EO is essentially a detailed business plan that fully describes the proposed commercial product or service.

Entrepreneurial Offers are intended to rely solely on private investment and, thus, should directly result in a profit-making opportunity for the investor. Due to their profit-making nature these enterprises should be fully capable of funding all flight costs. As a result, the standard price for space flight via an EO is $20.8 million per site bundle.[1] Additional costs are incurred for crew time, crew training, stowage space, and space shuttle cargo transportation. In addition to the costs incurred, the investor must also navigate all hardware manufacture, payload integration, and other flight rules and regulations on their own or with a service provider such as SPACEHAB or Instrumentation Technology Associates (ITA).

Collaborative research arrangements with the CSCs are the cornerstone of current commercial space-based research efforts. Overseen by Space Product Development (Code U), NASA currently sponsors 17 CSCs to foster joint academic and industry partnerships in specific areas of commercial research. Each CSC receives a fixed level of research funds from NASA and leverages this grant to secure commercial and academic funding.

Unlike EOs, these partnerships are meant to focus on formative or evaluative research that should, in the long term, lead to commercially viable products, services, or processes. Due to their lack of short-term profit generation, research conducted via a CSC partnership is not subject to the standard price flight costs. In fact, industry sponsors have participated in CSC research for as little as $10,000 or an in-kind contribution. Moreover, the CSC typically facilitates all hardware manufacture, payload integration, and other flight details. Industry is thus able to fully leverage the knowledge and experience of the CSCs.

[1] This includes the year-long rental of one research rack aboard the ISS along with the material resources to support research on that rack. Few companies are likely to need a complete research rack for this length of time, so the costs for most companies that present EOs are likely to be lower than this figure.

Chapter 2: The State of Microgravity Research

As noted in the previous section, it is not within the scope of this study to identify the "best" areas of space-based research or best space research applications. However, a basic understanding of the field and its potential is essential to identifying target industries and constructing the messages to reach these industries.

Space provides three important benefits that can be exploited for research and manufacturing: a microgravity environment, a vacuum, and a unique vantage point for looking towards Earth and out into space. Of these, the first is the most unique and offers the best potential for research in partnership with NASA and, more specifically, research aboard the ISS. Therefore, a brief overview of microgravity applications is presented here, with a view to linking these to the specific industries that are the most viable targets for our outreach program.

Early forecasts of space activities and uses focused more on ideas such as space-based manufacturing and energy generation (e.g., *Long-term prospects for developments in space*, 1977[3]), satellite communications, and space-based imagery for making weather forecasts, studying land use patterns, and identifying oil, natural gas, and mineral deposits. Early reports also recognized the value of space for tourism, entertainment, and education (e.g., *Space Industrialization: Final report*, 1978[3]), and identified on-orbit services, related ground support, and space transportation as important areas for space commercialization (e.g., *Commercial Space Industry in the Year 2000: A Market Forecast*, 1984-85[3]).

Some of these predictions have come to pass—there is now a thriving space industry in satellite communication, space-based imaging, and space transport. Space-based manufacturing, however, is still far in the future. Instead, scientists are now emphasizing the value of microgravity for conducting research that will lead to new products and materials and improvements in earth-based production processes. A 1995 report[9] by the National Academy of Sciences (NAS) concluded:

> *"It should be recognized that, to date, no examples have been found of materials that are worthy of manufacture in space. Unless and until such examples are found, space manufacturing of products should be deemphasized as a reason for undertaking microgravity research."*

To lay the foundation of a mature microgravity research program, a number of studies have attempted to identify areas that reflect realistic future opportunities.[1, 7, 9-12] They have variously concluded that the following fields of research show promise: the study of fluids (i.e., multiphase fluids, phase separation, transport phenomena, and thermophysical properties of melts); crystal growth (i.e., growth of bio-materials such as protein crystals used in rational drug design, and inorganics used in semiconductors and thin-film applications); metals and alloys (i.e., thermophysical properties and solidification behavior); combustion science (i.e., combustion processes and fire suppression technology); microgravity physics (i.e.. nucleation and metastable states); combustion synthesis (i.e.. development of new forms of polymers, ceramics or glasses); and extraterrestrial processes and technology development (i.e., space-based processes that exploit the properties of space and use materials found in space). (See Table 3 for a summary of the microgravity research areas recommended by each of these reports.)

Table 3:
Summary of Conclusions from Documents Assessing Microgravity Research

Document Title	Author & Year	Recommended Directions for Future Research
Microgravity Research Opportunities for the 1990s[9]	National Academy of Science, 1995	Fluids and transport* Metals and alloys* Microgravity physics* Certain areas of biotechnology* Polymers Ceramics or glasses Inorganic crystals Epitaxial growth
Future Materials Science Research on the International Space Station[12]	National Materials Advisory Board, 1997	Nucleation and metastable states Prediction and control of microstructures, pattern formation and morphological stability Phase separation and interfacial phenomena Transport phenomena Crystal growth, defect generation and control Extraterrestrial processes and technology development (e.g., space-based processes that exploit the properties of space and use materials found in space)
A World Without Gravity[10]	European Space Agency, 2001	Thermophysical properties of melts and other fluids Solidification behavior of metals and alloys Crystal growth of semiconductor and sensor materials Combustion phenomena and processes Study of complex multiphase fluids Crystallization of bio-molecules (proteins) for structure determination Cell science and bioreactor technology Human physiology and medicine

*strongly recommended

Although these reports identify fundamental phenomena or processes affected by the microgravity environment, they provide only a tertiary look at the industries that may benefit from their study. Many phenomena studied in microgravity have applications across a range of industries. For example, the study of the fluid dynamics that affect crystal growth is relevant to a variety of industries such as biotech, pharmaceuticals, industrial chemicals, polymers and plastics, and semiconductors.

Moreover, the field of microgravity research is still so new and untested that it is premature to pin down the best and most viable applications of a particular process. As the NAS report concluded:

> *"To date, only a limited number of microgravity experiments have been conducted in space with completed analyses and reports of results. The total experience of U.S., Canadian, Japanese, and Western European scientists is less than 1000 hours for experiments in orbit. Because of the limited results available, the strategic recommendations in this report cannot be highly detailed or exclusive[9]."*

Overall research in microgravity is limited, and, therefore, the ability to evaluate its potential is also limited.

In addition, most current investigations are still at the stage of identifying, measuring, and categorizing microgravity phenomena. Scientists are still discovering, for instance, that a microgravity environment facilitates the growth of some crystals, but have not yet identified with certainty which kinds of crystals are affected, what experimental parameters are necessary for this procedure, or why this occurs. Thus, further study is needed before microgravity phenomena are understood well enough for the most useful applications to be identified and parlayed into technological advances on Earth. Furthermore, experimental results need to be painstakingly replicated and catalogued to develop a body of knowledge in this field.

Partly because of its nascence as a discipline, and partly because of its conceptual novelty, the field of microgravity research currently offers few essential "solutions" to known industrial problems although it has very great potential to do so. Humans have always operated in a gravitational environment and processes and mechanisms have been developed to work within and with the force of gravity. Looking at these processes in microgravity allows for a fresh and different perspective that raises a lot of new, interesting questions and carries a lot of potential, but is still far from offering solutions to practical problems. After a thorough review of microgravity research applications, we were unable to identify any research directions that offer "turnkey" solutions to problems faced by our target industries. Microgravity research has the potential to answer many questions and solve many problems, but there is considerable uncertainty as to what those questions are and when those answers will be forthcoming. Thus, a microgravity research program is unlikely to compete with a company's terrestrial R&D programs for money and resources. It is a high-risk proposition, and while companies do undertake high-risk research projects if they carry the promise of dramatic gains, the current state of microgravity science does not allow a clear and plausible picture of potential gains.

The microgravity environment is a major technological breakthrough that permits a fundamental paradigm shift in theoretical and applied science. As two examples, consider the behavior of flames and fluids. On Earth the forces of gravity create pear-shaped flames that direct heat upward. In space, the lack of gravity creates spherically shaped flames radiating heat more evenly. Similarly, Earth's gravity causes fluids to ultimately separate with the heaviest fluids resting at the bottom of a container. In space, the weight of fluids is no longer impacted by gravity; fluids mix evenly and remain suspended. The examination of such fundamental processes may lead to significant advances in the future. However, major paradigm shifts are rarely easy or quick. Take the discovery of the vacuum at the turn of the twentieth century, which revolutionized microelectronics *over the course of the last hundred years*. We expect that it will be several years before the potential of microgravity is understood fully, and several more before it is translated into dramatic new products and commercial successes.

This does not mean that there will not be some immediate practical gains from microgravity research studies. Indeed, there have already been some notable commercial successes, such as the *Zen* fragrance created by International Flavors and Fragrances or the improved casting process developed by Ford Motor Co. as a result of findings related to fluid properties in microgravity. However, as noted by NAS:[9]

> "*The justification for microgravity research must continue to be the promise of advances in areas of fundamental and applied science*."

The greatest gains in this field will result from a concerted program of study that aims to explain and understand how certain fundamental or industrial production processes are affected by microgravity. It is basic research that will drive the development of microgravity research.

CSC Research

For many years, the CSCs have been studying microgravity phenomena that can impact terrestrial production processes. They have also made inroads into attracting industry investment in this research. The CSC experience is thus a more accurate indicator of what research is seen by industries as relevant and viable and, therefore, worth the investment. The next section contains a brief review of the CSCs and the areas in which they work.

CSC research covers a wide range of topics, and nearly half of the Centers' experiments leverage the unique microgravity environment of space.[2] The ISS, although providing the longest duration environment, is not the only environment available for microgravity research. Other shorter-duration experiments can be conducted utilizing drop-towers, Parabolic flights, sounding rockets, and Space Shuttle flights. The CSCs play a key role in advising industry partners as to the most economical and effective way of securing a microgravity environment for their specific research study. Furthermore, their expertise in microgravity research and space flight hardware development is invaluable to industry partners. In addition, they serve as important buffers between NASA rules and regulations and industry needs. Beyond these benefits they also create collaborative networks highly valued among their partners.

Partnership with a CSC can take two forms: sponsorship or consortium membership. When acting as a sponsor, industry partners help to underwrite research costs on a specific project or series of projects. These projects may be initiated either by the CSC or by an industry sponsor. Any resulting intellectual property is typically licensed either to industry or jointly shared between industry and the CSC. Under the consortium model, groups of industry partners pay a flat fee toward the conduct of experimental research, which is usually conceptualized, developed, and conducted by the CSC. In this instance, the intellectual property is typically licensed to all members of the consortium.

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[2] Much CSC research is conducted without access to microgravity. For example, the Food Technology Commercial Space Center at Iowa State University develops food for astronauts and conducts its research largely on Earth, as do other Centers focused on satellite and wireless systems or the development of space power technologies. Others, such as the Commercial Space Center for Engineering (CSCE) at Texas A&M University, merely utilize the ISS as a testbed for space applications including solar arrays, antennas, sensors, and other satellite components.

The tables and figures on the next few pages describe the CSC's current projects and partnerships. Of the 17 CSCs, three are involved in ground-based research unrelated to microgravity, and two others (ECSCTC and SCTC) use space simply as a test-bed for aerospace-related products such as solar arrays and satellite components (see Table 4 for details on CSC involvement by industry sector). Their work is therefore less relevant to the scope of this project.

The rest of the CSCs are engaged in microgravity-related research, although they may also have ground-based or test-bed projects either to support microgravity research projects or separate from them. Of the CSCs engaged in microgravity research, three are involved in biotech research, three in agritech research, and nine in materials and processes research.[3] Within materials and processes, six examine electronic and optical components, five heavy machinery and automotives, three metals and metal products, two chemicals, and two ceramics (see Table 5 for details on CSC involvement in materials and processes industry sectors).

The CSCs have also been very successful at engaging industry partners. As of 2001, nearly 120 firms were partnered with various CSCs (see Figure 1 for an overview of CSC industry partnerships, and Table 6 for a list of industry partners by sector). A majority of these partnerships fell within our target industry sectors, with 33 biotech firms, seven agritech and over 50 materials and processes firms engaged in microgravity research with the CSCs (see Table 6).

Of the firms in the materials and processes field, 18 firms are in the electronics and optical components sector, 13 in heavy machinery and automotives, six in chemicals, five in ceramics, three in metals and metal products, and seven in various other sectors (see Table 7 for a list of CSC partners by materials and processes sector).

These partnerships have resulted in 18 patents and six licenses in the field of biotech, three agritech licenses, and six patents and five licenses in the field of materials and processes. In addition, the CSCs have filed nine ground-based (i.e., not microgravity-related) patent applications, issued three licenses for ground-based technologies, and filed one patent and issued one license for products that have used space as a test environment. (See Figure 2 for the number of patents and Figure 3 for the number of licenses per sector).

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[3] As Table 3 shows, some CSCs conduct research in more than one area.

Table 4:
CSCs Working in Each Industry Sector

Microgravity Research Applications[4]			Applications Not Relevant to Microgravity Research	
Biotech.	Agritech	Materials and Processes	Use space as a test-bed for aerospace applications	Ground Based, non-microgravity related applications
BioServe CBSE CCACS	BioServe FTCSC WCSAR	CAMMP CCACS CMDS CSCE CSP CSPAE SDC SVEC WCSAR	ECSCTC SCTC CSCE CSP FTCSC SVEC WCSAR	CSHCN MITAC PVT BioServe CAMMP CBSE CCACS CMDS CSCE CSP CSPAE ESCSTC FTCSC SCTC SDC SVEC WCSAR

Shaded cells represent CSCs that work exclusively in that area.

Acronyms:
BioServe: BioServe Space Technologies, University of Colorado - Boulder and Kansas State University
CAMMP: Center for Advanced Microgravity Materials Processing, Northeastern University
CBSE: Center for Biophysical Sciences and Engineering, University of Alabama - Birmingham
CCACS: Center for Commercial Applications of Combustion in Space, Colorado School of Mines
CMDS: Consortium for Materials Development in Space, University of Alabama - Huntsville
CSCE: Commercial Space Center for Engineering, Texas A&M University
CSHCN: Center for Satellite and Hybrid Communication Networks, University of Maryland
CSP: Center for Space Power, Texas A&M University
CSPAE: Center for Space Power and Advanced Electronics, Auburn University
ECSTC: Environment Systems Commercial Space Technology Center, University of Florida
FTCSC: Food Technology Commercial Space Center, Iowa State University
MITAC: Medical Informatics & Technology Applications Consortium, Virginia Commonwealth University
PVT: ProVision Technologies, Stennis Space Center
SDC: Solidification Design Center, Auburn University
SCTC: Space Communications Technology Center, Florida Atlantic University
SVEC: Space Vacuum Epitaxy Center, University of Houston
WCSAR: Wisconsin Center for Space Automation and Robotics, University of Wisconsin - Madison

[4] We include here research that seeks to fully leverage the microgravity environment provided by space. For example, BioServe is included as such an application because its research *uses* the microgravity environment to study molecular structure. MITAC is not included as an application because its research on data transmission systems is *conducted in* but does not *use* the microgravity environment.

Table 5: CSCs per Materials and Processes Industry Sector

Electronic & Optical Components	Metals & Metal Products	Heavy Machinery & Automotives	Chemicals	Ceramics
CAMMP CCACS CMDS CSP CSPAE SVEC	CCACS CSP SDC	CCACS CSCE CSP CSPAE SDC	CAMMP CCACS WCSAR	CCACS

Acronyms:

CAMMP: Center for Advanced Microgravity Materials Processing, Northeastern University
CCACS: Center for Commercial Applications of Combustion in Space, Colorado School of Mines
CMDS: Consortium for Materials Development in Space, University of Alabama - Huntsville
CSCE: Commercial Space Center for Engineering, Texas A&M University
CSP: Center for Space Power, Texas A&M University
CSPAE: Center for Space Power and Advanced Electronics, Auburn University
SDC: Solidification Design Center, Auburn University
SVEC: Space Vacuum Epitaxy Center, University of Houston
WCSAR: Wisconsin Center for Space Automation and Robotics, University of Wisconsin - Madison

Figure 1:
CSC Industry Partnerships by Sector

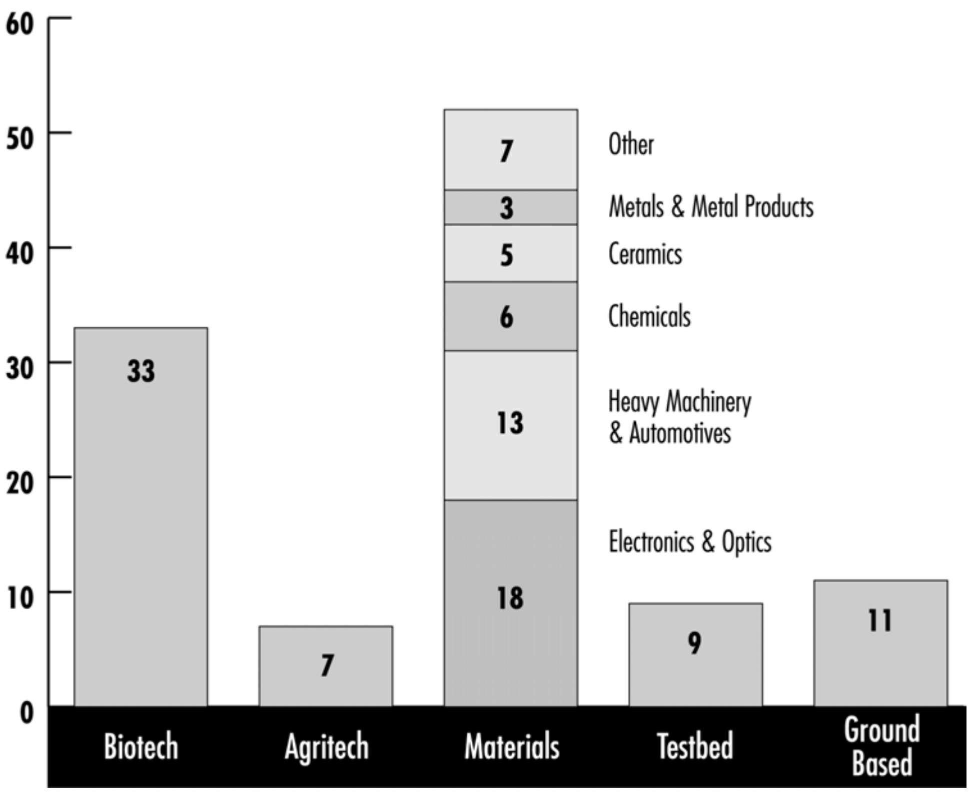


Table 6: CSC Industry Partners by Type of Research Conducted

Biotech

- 3-Dimensional Pharmaceuticals
- Abbott Laboratories
- Agouron Pharmaceuticals
- ALK A/S, Denmark
- Amersham Life Science
- Amgen
- AngioTech Pharmaceuticals
- AnorMed, Inc.
- Atlantic BioPharmaceuticals, Inc.
- BioCryst Pharmaceuticals, Inc.
- Bio-Rad, Inc.
- BioVir Labs, Inc.
- Bristol-Myers Squibb
- Calbiochem, Inc.
- Cubist Pharmaceuticals, Inc.
- DuPont Pharmaceuticals
- Glaxo Wellcome
- Great Plains Diabetes Research Inc.
- Informed Diagnostics
- Invitrogen
- Merck
- Monsanto/Searle
- New Century Pharmaceuticals Inc.
- Oncogene Research Products
- Parke Davis
- Pfizer Central
- Research
- Research Genetics, Inc.
- Schering-Plough Research Institute
- Shearwater Polymers, Inc.
- Smith Kline Beecham Pharmaceuticals
- Sulzer Orthopedics Biologies, Inc.
- The Upjohn Company
- Vertex Pharmaceuticals

Agritech

- Aeroponics
- American Ag-Tec International, Ltd.
- Bristol Mums, Inc.
- Plant Biotechnology Co.
- Producers' Natural Processing Inc.
- Sanderson Farms
- The Timber Company

Materials & Processes

- American Foundry Society
- Anter Corporation
- Applied Optoelectronics
- Brimrose Corporation
- Brush Wellman
- Busek Corporation
- Citation Corporation
- CoorsTek
- Dupont
- Dynatherm
- Environmental Engineering Concepts
- Flow Simulation Services
- Ford Motor Co.
- Frogswitch Mfg. Co.
- Givaudan Roure Corp.
- GM Powertrain Group
- Guigne
- Harmony Castings Co.
- Herman Williams Co.
- Hewlett-Packard
- Honeywell
- In Space propulsion
- Infrared Fiber Systems
- Innovative Scientific Solutions, Inc.
- Intelligent Optical Systems
- Intermagnetics General Corporation
- International Flavors and Fragrances Inc.
- International Stellar Technologies, Inc.
- ITN Energy Systems
- K+P Agile Inc.
- Laempe+Reich Inc.
- Lucent Technologies
- Maynard Settle Casting
- Meadowlark Optics
- Metal Oxides Techolgies
- Optopower, Inc.
- OPTS Inc.
- Ormet Corp.
- Physical Science, Inc.
- Pioneer Hi-Bred Intl., Inc.
- Polaroid
- Procter & Gamble
- Professional Metallurgical Services
- Shott Fiber optics
- Solar Turbines
- Stahl Specialty Co.
- Sulzer Orthopedics Biologie
- TDA Research
- Texas Diode Corporation
- TPRL, Inc. West
- United Advanced Technologies, Inc.
- Vermont American Inc.

Test-bed

- Boeing
- Hughes Space and Communications
- In-Pod
- Lockheed-Martin
- PetroSat
- SpaceDev, Inc.
- Spacehab
- TecStar
- TRW Space & Technology Division

Ground-based

- Airsys
- Children's Hospital of Michigan
- Diagnostica Center
- Viseton Corp
- Estee Lauder Companies
- Exstream Water Technologies
- Microsoft
- Molecular Simulations
- Optron Systems
- Tyco-U.S. Surgical
- WTC/PentaPure Corp.

Table 7:
CSC Industry Partners in the Field of Materials and Processes
(Breakdown by Industry Sector)

Metals & metal products	Heavy machinery & automotives	Electronic & optical components	Chemicals	Ceramics
Brush Wellman Inc. Metal Oxides Techolgies Ormet Corp.	American Foundry Society Ford Motor Co. Frogswitch Mfg. Co. GM Powertrain Group Harmony Castings Co. In Space propulsion K+P Agile Inc. Laempe+Reich Inc Lucent Technologies Maynard Steele Casting Co. Solar Turbines Stahl Specialty Co. Vermont American Inc.	Anter Corporation Applied Optoelectronics , Inc. Brimrose Corp. of America Hewlett-Packard Honeywell Infrared Fiber Systems, Inc. Innovative Scientific Solutions, Inc. Intelligent Optical Systems Intermagnetics General Corporation International Stellar Technologies, Inc. Lucent Technologies Meadowlark Optics Optopower, Inc. OPTS Inc. Ormet Corp. Shott Fiber optics Texas Diode Corporation TPRL, Inc. West	Dupont Givaudan Roure Corp. International Flavors and Fragrances Inc. Pioneer Hi-Bred International, Inc. Polaroid Procter & Gamble	Guigne Sulzer Coors Tek ITN Energy Systems TDA Research

Figure 2:
Patents Resulting from CSC Partnerships by Industry Sector

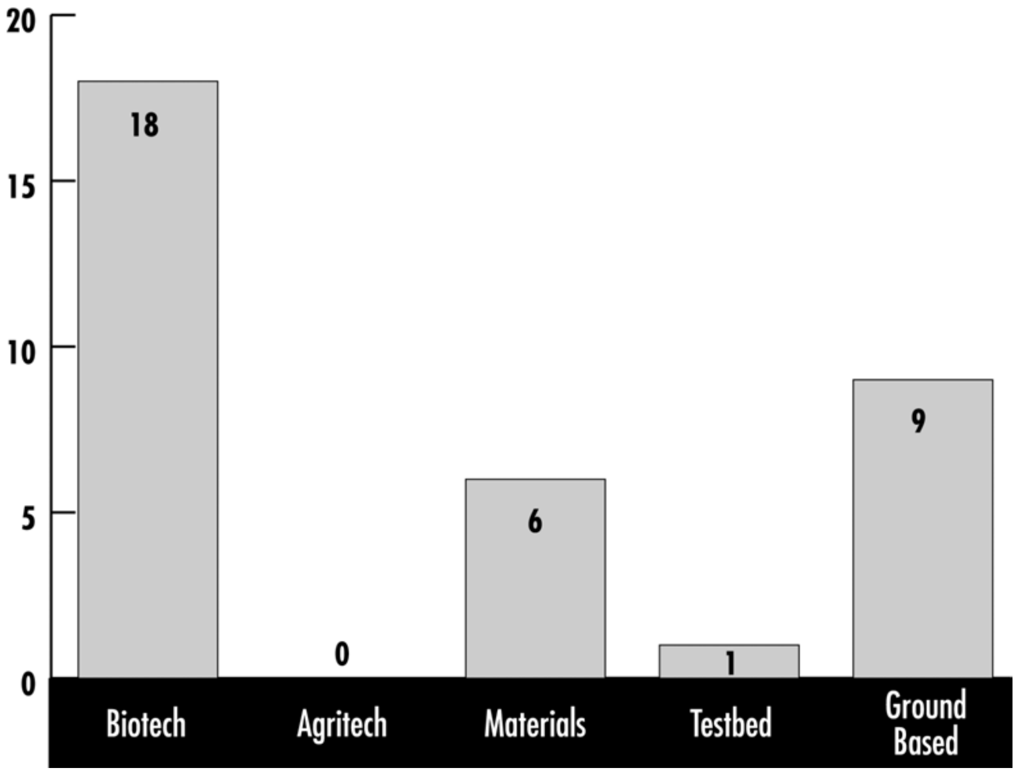
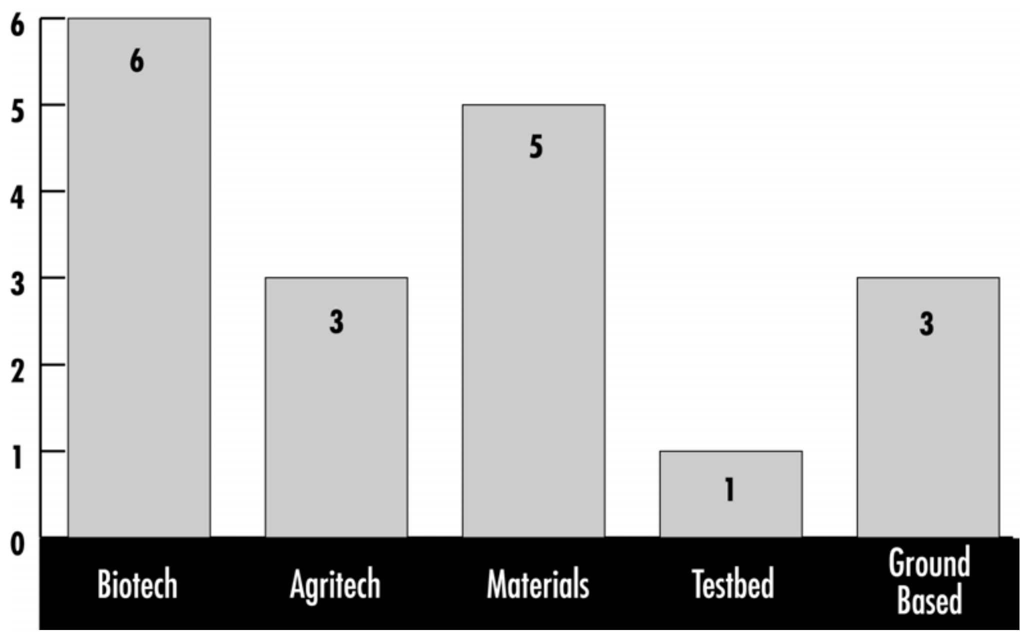


Figure 3:
Licenses Resulting from CSC Partnerships by Industry Sector



Chapter 3: Microgravity Applications in Industry

The statement of work identified three target industry sectors for this outreach plan: Biotechnology, Agritech, and Materials and Processes. These industry sectors are briefly described in this section.

The term Biotechnology is used loosely in the statement of work to include a host of medical applications, not just those that rely on cellular or molecular processes for product development. Thus, this sector is more accurately titled the "Biomedical" sector in this report, and covers biotech and non-biotech medical applications of microgravity research.

Biomedical

The Biomedical sector, also sometimes termed the Medical Substances and Devices sector, comprises at least four distinct but overlapping sectors – pharmaceutical drugs, medical instruments, biological drug products, and diagnostic products. In terms of revenue and actual R&D spending, the pharmaceutical sector dominates this category by far, but other sectors, such as the biological products sector, may be growing at a faster pace. In 1997, this sector had, by far, the highest combined R&D intensity (i.e., the ratio of R&D expenses to sales), 11.8%.[13]

Microgravity research for medical applications has focused on the following areas:

- The study of human system changes in microgravity, such as bone and muscle loss, immune suppression, or electrolytic regulation problems, that model certain disease processes.
- Testing of drugs for these disease states and studies of antibiotic effectiveness.
- Growth of macromolecular and protein crystals (for better understanding of their structure and function).
- Antibiotic fermentation processes and other biochemical secretions.
- Tissue culture, cell growth, and proliferation.
- Biochemical separations.
- Micro-encapsulation techniques for better drug delivery systems.
- Development of new biomaterials such as porous ceramics through processes like combustion synthesis and thin film depositions.

With the increasing use of rational drug design techniques, the perceived utility of such research is likely to grow.

Medical Biotechnology

Biotechnology refers to a whole host of industries that use cellular or molecular processes to solve problems or make products.[14] Although biotechnology serves both medical and non-medical markets, the medical market is the dominant sector. Today, over 1,200 biotechnology firms exist in the U.S. and nearly a quarter of these are publicly held.[14] The biotechnology industry has experienced rapid growth with revenue doubling from $8 billion in 1993 to over $20 billion today.[14] Biotechnology is the most research-intensive of all civilian manufacturing industries, with R&D expenditures approaching $11 billion in the year 2000.[15] Biotechnology is also one of the more heavily regulated industries: the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), and the Department of Agriculture (USDA) have oversight responsibilities.

Medical applications of biotechnology focus on developing products to diagnose, prevent, treat, and cure disease. Nearly 120 biotechnology drug products and vaccines have received approval by the FDA and over 350 more are currently in clinical trials.[14] Reflecting biotechnology's rapid growth, 75% of biotechnology-generated drugs on today's market were granted approval in the last six years.[14] Biotechnology firms are targeting the development of products to treat cancer, AIDS, Alzheimer's, Parkinson's, arthritis, and stroke.[15]

Traditionally, the medical biotechnology sector functioned as a service provider to large pharmaceuticals. Its role was to develop technologies or identify targets and then sell or license them to pharmaceutical companies, which then developed and marketed products based on these technologies. In the last five years, however, market forces have compelled biotech firms to move up the value chain, leading to pharmaceuticals taking a more active role in rational drug design, so now there is considerable overlap between these two sectors. Still, the biotech sector is smaller, less established, more competitive, and more actively engaged in cutting-edge technology. It is especially reliant on "IP"—a company's intellectual property (by way of patents, techniques, products, or technologies) is weighted more heavily into its market valuation relative to other industries.

Pharmaceuticals

The U.S. pharmaceutical chemicals industry is estimated at $14.6 billion and is predicted to grow at about 7% annually.[16] Leading pharmaceutical companies invest about 12% to 25% of their revenues on R&D, a third of which is typically spent on research (the rest is spent on bringing the product to market, including clinical trials). These companies face an increasingly competitive market that rewards only true innovation, and companies typically have a limited time to recoup the bulk of their investment (i.e., until their patent protection expires). Bringing a product to market soon is therefore a primary concern.

Companies typically have a "portfolio" of high- and low-risk projects with near- and long-term payoffs. They also assess their portfolio in terms of the competition; if a competitor is farther along a particular research direction, the company will often abandon that research. Pharmaceuticals rely heavily on "acquiring" research from universities as well as smaller research-focused companies (including biotechnology companies) for the most "cutting-edge" research, since this allows them to hedge their exposure to the uncertainties inherent in advanced research.

For years, pharmaceuticals have relied on a mix of serendipity and informed guesswork to identify possible targets and sources for drugs. In recent years, the industry is switching to rational drug design—i.e., understanding disease processes and mechanisms and developing molecules that can block or promote specific biochemical reactions. Thus the pharmaceutical industry can benefit from the study of the body's response to microgravity, which mimics certain disease and aging processes such as muscle and bone degeneration. This industry can also benefit from testing drugs for these diseases in microgravity; since these processes are accelerated in microgravity, the effects of drugs over a longer period of time and in more severe conditions can be studied.

Other Medical Products

Microgravity research also holds immense potential for other medical equipment and devices, most notably prosthetic limbs and implants. Biomedical applications converge with materials science in the development of biomaterials and porous ceramics that can be used for such limbs and implants. There are more than 500 companies engaged in developing prosthetic limbs and implants.[17] This market has seen a trend towards consolidation, but it also continues to attract new entrants.

The global medical device industry was valued at $137 billion in 1997[18], with the U.S. holding 42% of the global market share (i.e., $57.7 billion). This category comprises more than 130,000 medical devices used for the diagnosis and treatment of medical conditions, and many of these can benefit from processes such as containerless processing and surface deposition techniques (e.g., for sensors). Another important application is in the area of tissue engineering, which has seen explosive growth in the last few years.

Agritech

The nonmedical market covers biotechnology applications in agriculture and industry. Agricultural applications include making crops more resistant to pests and disease, creating seeds of higher quality, or developing foods with greater nutrient quality. This market is estimated to grow approximately 20% per year rising from $285 million in 1996 to nearly $1.7 billion by 2006.[15] According to an analysis by Ernst & Young conducted in 2000, agricultural biotechnology employs nearly 22,000 people, generating over $2 billion in revenues when the contributing industry's inputs, supplies, and goods are included.[19] Like the biotechnology field, agritech firms invest heavily in R&D and global expenditures on R&D were estimated at approximately $1 billion in 1997.[15]

Agritech uses genetic engineering to achieve what every farmer wants: crops that yield more and better-tasting food products, and resist disease and pests. It is argued that agritech complements rather than replaces traditional methods of improving agricultural products and provides an abundant and safer food supply that is less reliant on chemical pesticides.[15] It is portrayed as a more precise way of achieving what farmers and nature have done for years—developed crops with specific desirable qualities. Despite these arguments, consumers have remained leery of genetically engineered foods. For example, even though BST—a hormone that increases milk yield—received approval in 1993 many consumers nonetheless fear its effects and some milk is marketed as BST-free. Even greater controversy exists around the production of genetically modified seed with some farmers concerned that large biotech companies such as Monsanto might develop a seed supply monopoly and come to control world food production. NASA should be mindful of consumer concerns regarding genetically modified food products as it attempts to partner with the agritech industry.

Agritech also employs biological products and processes such as micropropagation, fermentation and biocultures, plant and animal health diagnostics, vaccines, and biopesticides.[15] Biotech enzymes used for cheese manufacturing and hormones that increase milk production are on the consumer market, as are a large number of biopesticides used to increase yield, and prevent disease and pest infestation.[15] Agritech products are used in food production and food preservation applications. In general, these applications of biotech are less well-known and less controversial.

To date agritech-based microgravity research has focused on

- The study of plant growth, transformation, and development (including plant orientation in gravity, cell division and elongation, and production of flowers, fruits, and seeds),
- The study of gene transfer,
- The study of fermentation processes, and
- The production of plant antibodies.

Both the Medical Biotech and Agritech sectors are impacted by the following factors:

Dominance by large companies

Biotechnology sales are dominated by products from a few companies such as Amgen, Genetech, and Monsanto. For example, Epogen, a blockbuster Amgen treatment for anemia in dialysis patients, at one time accounted for 25% of all biotechnology.[15] In addition, while the mean number of employees at biotechnology firms is 104, the median number is 30 employees. In fact, two-thirds of biotechnology firms employ fewer than 135 people.[15]

Volatile company valuation and funding

The biotechnology sector has been hit hard in the current economic downtown. For example, the NASDAQ Biotechnology Index had soared to a high near 1600 but was hovering under 1000 at the start of 2001.[20] Beyond a fluctuating stock market, biotechnology is also challenged by securing and retaining capital. By its nature, biotechnology is an industry that requires extensive investment in product development, even though many of these may never generate any profits. To reduce these risks and increase their funding, a number of biotechnology firms have partnered with other firms both in the U.S. and abroad.

Restrictive regulatory processes

As noted above, the FDA, EPA, and USDA regulate biotechnology. These agencies impose operating costs and constraints intended to assure public health, safety, and environmental goals.[15] Perhaps the most comprehensive of all these agencies is the FDA, whose regulations, coupled with the uncertainty of drug development, make medical biotechnology a high-risk endeavor. Biotechnology firms typically find that only one of every five drugs that begin clinical trials ultimately receives FDA approval. Besides being risky, the approval process can take up to 15 years and cost up to $500 million.[21]

Other Biotech Applications

Industrial applications of biotechnology include enzyme and specialty chemical creation and bioremediation.[15] Industrial enzymes are used for cleaning products; animal feeds; pulp and paper production; and the processing of textile, starch, leather, and food. Specialty and fine chemicals can be used in pharmaceuticals, food additives, dyes, agrichemicals, and detergents. This market is estimated to grow 19% per year rising from $275 million in 1996 to $1.6 billion by 2006. Biotechnology materials, specialized software and drug development, and production equipment are important adjuncts to these core markets.[15]

Materials & Processes

The category of advanced materials includes a variety of materials with exceptional structural or conductive properties. One report[22] categorizes this sector as including the following kinds of materials:

- Polymers (including conductive polymers)
- Metals and alloys (including metal matrix composites)
- Advanced ceramics
- Organic composites
- Reinforcing fibers (including nanotubes)
- Abrasives and ultrahard materials
- Carbon-carbon composites
- Electronic, magnetic, and optical materials (e.g., non-linear optical materials, photovoltaic materials, and piezo-electric materials)
- High-temperature superconductors
- Innovative and smart materials (such as biomaterials and ER fluids)

The production and use of these materials spans many industries and there is considerable overlap among these categories. Organic composites, for instance, have applications in aerospace, defense, automotives, mass transportation, and the sporting goods market. Similarly, the category of advanced ceramics includes structural ceramics (for wear parts, bioceramics, cutting tools, and engine components), electrical ceramics (used in capacitors, insulators, ICs, magnets, superconductors, and piezo-electrics), ceramic coatings (used in cutting tools, wear parts, and engine components) and chemical and environmental ceramics (such as filters, membranes, catalysts, and catalyst supports).[23]

The identification of discrete industry sectors becomes even more difficult when one considers advanced industrial processes. The key industrial processes affected by microgravity—such as metallurgical processes, solidification design, crystallization, filtration and catalysis, containerless processing, and manipulation of microstructures—have applications across a variety of industries from biotech to automotives.

This led KPMG to conclude[2]:

> "*[Materials science] is not an industry category nor could it be characterized as a market in and of itself. Materials research is an activity conducted on behalf of numerous industries and serves many purposes . . . Process research is aimed at determining and improving upon various physical phenomena that are key to many NASA missions and industrial business activities. Like materials research, process research can be applied to a number of industries for many different purposes.* "

Nevertheless, this report also identified the following categories in this sector:

- Electronic and photonic materials (primarily the semi-conductor industry)
- Ceramics
- Metals and alloys
- Polymers
- Combustion
- Fluid Physics

Of these, the first four are industry sectors, while the latter two are processes that may apply to different industries. For example, the study of combustion is relevant for the power generation, heavy machinery (e.g. turbines, etc.), automotive, and fire suppression industries, as well as those that develop new materials through combustion synthesis. Similarly, fluid physics has application in virtually all areas of material science, combustion, and biotechnology.

Based on our understanding of the science, other market research reports, the CSC industry partners, and the business marketplace, we have identified five industry sectors that can benefit from microgravity research. A brief analysis of these sectors and their relevance to this outreach effort follows. We have tried to identify what segments of each industry sector can benefit most from microgravity research, and to gauge the overall relevance of microgravity research for that industry sector.

Metals and Metal Products

This industry sector can be roughly divided into ferrous metal products, non-ferrous metal products, and companies that specifically deal with metal fabrication and casting. Within this industry, there is also a subset of companies that make specialty metal products, including specialty steels and metal matrix composites.[5] The automotive industry is the largest client for specialty metals with superior structural properties. The consolidated nature and global scope of the automotive industry allow it to exert enormous pressure to keep this industry highly price-competitive and innovative. Technological innovation is critical to this industry, both to achieve significant cost reduction (through more efficient processes) and to keep up with the automotive industry's demand for new materials.

Since this industry is highly focused on the behavior of materials in the molten state, it can benefit from microgravity research in at least three ways:

1. More accurate measurement of thermo-physical properties of melts and other fluids to improve scientific models of melt processes such as casting, welding, etc.
2. Better understanding of fluid processes and the solidification behavior of metals and alloys through reduction of convective forces.
3. Possibility of making new materials (that cannot be developed under the influence of gravity), either by mixing melts with highly different specific gravities or more even suspension of particulates within metals.

[5] Metal matrix products are manufactured by infiltrating porous ceramic forms with liquid metal. Easy variation of these components enables the tailoring of material properties for specific use.

Heavy Machinery and Automotives

This category consists of large, multinational corporations that manufacture heavy machinery, engines, turbines, automotives, airplanes, and other industrial equipment. This is a very mature and well-consolidated industry sector, with a few large companies (and their subsidiaries) vying for market share of a variety of products ranging from agricultural machinery to aviation equipment.

This sector serves as a demanding market for specialty and advanced materials, as well as technologies for more efficient fuel conversion and energy transfer. It develops products for industry and for consumers, and relies on consumer confidence and goodwill to differentiate the consumer products. It is constantly driven to improve efficiency—i.e., offer greater motor energy using less fuel and producing less waste material.

A host of microgravity research applications are relevant to this sector:

1. Understanding of combustion processes for more efficient energy conversion.
2. Understanding of catalytic processes for more efficient energy conversion
3. Chemical separation and filtration processes have relevance for fuel purification, and therefore cleaner and more efficient combustion.
4. This sector is one of the largest markets for advanced materials with better structural properties and for better fabricated materials. Thus it drives innovation in the metals, ceramics, and casting industry.
5. Development of abrasive crystalline materials (through crystal growth or thin film deposition) for use in machine parts such as drill bits.

Chemicals

The chemicals industry can be segmented into three areas: (1) Basic chemicals, largely consisting of industrial organics and inorganics, and making up close to half the total chemicals market; (2) Intermediates, including fine chemicals, specialty chemicals, plastics, synthetic rubber and synthetic fibers; and (3) Finished products, including chemical products, coatings and inks, and agrochemicals.

In recent months, this industry sector has seen declining values at par with the overall trend in manufacturing. Relative to commodity chemicals, the market for specialty chemicals is small in dollar value and not as mature, but market growth is higher. Also these companies retain flexibility in their production processes so they can customize products, and have a low turnaround time for new products.

Microgravity research is of most relevance for specialty chemicals such as performance polymers, catalysts, additives, pigments, and dyes—which make up about 6% of the total chemicals market. In particular, research on thin films and chemical separation is relevant for air and water filtration and fuel purification, and the study of organic macromolecules is relevant to the production of polymers and plastics. Some research has also focused on production of larger, more perfect, inorganic crystals (such as zeolytes), but this is not expected to impact production of industrial quality zeolytes.

Electronic and Optical Components[6]

Many of the technological advances in telecommunications have been and will be driven by the development of materials with superior and controllable electrical and optic properties. The semi-conductor market dominates this industry category. Semi-conductors are used in many industries including computer hardware, telecommunications, media, and even automotives. The market is fairly consolidated on the supply side with the top 10 companies providing two-thirds of the sales. While the basic technology is freely available, this industry is focused on carving out niche markets for customized applications and on increasing performance. Moore's law holds that microprocessor performance will double every 18 months, a prediction that keeps these companies constantly searching for new technologies. These technological innovations have also led to a steep drop in prices, making this market exceedingly price-competitive.

By all analyses, the semi-conductor industry is in a major slump, with revenues down 9-20% from 2000, in sharp contrast to a 25% predicted growth rate.[24] While traditionally this industry has had high R&D spending ($45.8 billion in 1997, or about 7% of total sales), this downturn has impacted the growth of the industry as well as its R&D budgets.[13]

> *"The $204 billion semiconductor industry is staring into an economic abyss that may stretch through next year in what economists are calling the fastest downturn in its history*."[23]

Ceramics

Ceramics are widely used in a variety of industries ranging from aerospace to household appliances. The industry is generally divided into the following categories: structural clay products, whitewares, refractories, glasses, abrasives, cements, and advanced ceramics. According to industry estimates, the world ceramics market grew by 40% during the 1990s and is poised to grow at about 7% annually up to 2004.[23]

Of these segments, abrasives (particularly synthetic abrasives) and advanced ceramics are the most likely candidates for microgravity research. Advanced ceramics includes four different kinds of ceramic materials.[23] (1) structural ceramics that are used in wear parts, bioceramics, cutting tools, and engine components, (2) electrical ceramics used in capacitors, insulators, integrated circuits, magnets, piezo-electrics, and superconductors, (3) ceramic coatings, used in engine components, cutting tools, and industrial wear parts, and (4) chemical and environmental ceramics used in filters, membranes, catalysts and catalyst supports. Advanced ceramics accounts for about 16% of the $50 billion U.S. ceramic market.[23] A major thrust in this area is to develop near-net shape-forming production processes to reduce the cost of machining, which may be up to 50% of the total manufacturing cost. Future growth is predicted in the areas of nanostructured materials, bioceramics, fuel cells, electrical ceramics, superconductors, and ceramic matrix composities.

Ceramics is generally regarded as a lower priority for microgravity research because it relies less heavily on fluid processes. However, there are some microgravity applications that are of great value to this industry. In particular, powder processing of highly reactive materials may benefit from containerless processing in space.

[6] This sector includes products such as semiconductors, LEDs, sensors, chemical separations, fuel cells, etc.

Prioritization of Target Sectors

Clearly, microgravity research impacts several industry areas and can, at least theoretically, affect every industrial process. In an effort to prioritize industry sectors for outreach, we have evaluated each of these sectors against the following criteria:

Relevance of existing microgravity research findings

One of the main barriers to industry participation is lack of data to demonstrate how that industry can be impacted by microgravity research. Industries for which the relevance of microgravity research is better demonstrated are more likely targets and should be given a higher priority in the outreach effort. As more research is conducted in other sectors, the focus of the outreach effort can be expanded to include them.

Ability to use basic research findings

Much of the current and near-term microgravity research is likely to focus on answering fundamental questions and developing explanations for physical and biological phenomena in microgravity. Industries that can find practical use for this kind of research are likely to support it in these earlier stages.

Large R&D budgets

Industries that are research-focused and support a competitive research environment are more likely to participate. Corporations in these industries value the strategic/competitive advantage of the opportunity and aspire to be perceived as leaders in science and technology.

Value of consumer support & publicity

One of the main benefits of participation in this effort is the company's ability to use the association with NASA to build confidence and goodwill among employees and customers. Industries in which individual companies compete for consumer attention and value their public image are more likely to appreciate this benefit of NASA's offer.

Table 8 below evaluates relevant industry sectors on these four criteria.[7] Based on this analysis, we recommend that early efforts to promote commercial microgravity research focus on the following industries:

- Biomedical. This is a priority area for a number of reasons. First, several known microgravity phenomena are relevant for this sector, and the current push towards more methodical and model-based product development increases the application of microgravity research in this field. Second, it is a rapidly growing sector, even in the current sluggish economy. Finally, thanks to the public's interest in health-related news and science, advances in this sector offer the best opportunity for showcasing microgravity research and making it more relevant to the general public.

[7] In this table we have separated the medical biotech and pharmaceutical sectors, even though they are rapidly converging. The table also includes an assessment of two sectors—environment and aerospace—that were not part of our original statement of work, but which we believe are important to this effort.

Relative to medical biotech, the agritech sector is less "popular" and more controversial.

- Metals and Metal Products. This sector is best positioned to benefit from the immediate application of fundamental fluid science research.
- Heavy Machinery and Transportation. This sector is also likely to benefit from a wide variety of microgravity research applications, including casting, development of new ceramic or metallic materials, fuel filtration processes, and better combustion processes. NASA can engage the large, multi-faceted corporations that make up this mature and well-consolidated sector in a variety of research applications to demonstrate a strong impact on this industry as a whole.
- Environment. This "sector" consists of a heterogeneous mix of companies working to develop technologies that increase efficiency and/or reduce waste and pollution. We have included this sector as a priority for two reasons. One, this is an area that interests the public; pollution is related to health and is seen as a personally relevant issue by a large segment of the population. Research advances in this sector can therefore be used to garner publicity for this enterprise. Second, this sector can be further nurtured by NASA (much like the aerospace industry) via spin-offs and spin-ons. Many of the technologies that NASA has developed to sustain life in space can be commercialized for use on Earth; conversely, the technologies that this sector is developing (e.g., in the areas of water recycling or chemical solid waste disposal) can be used by NASA aboard its spacecraft. There is thus a natural convergence between NASA's interests and this relatively undeveloped industry sector, and NASA can extend its efforts at cooperation and collaboration in this sector.
- Optical and Electrical Materials. After aerospace, this has been the industry sector that has traditionally worked most closely with NASA. Despite two major drawbacks—(1) it relies heavily on the technology transfer mechanism and (2) it has taken the brunt of the economic downturn—this sector is likely to remain one of the mainstays of the commercialization effort because of its constant push for innovation and product improvement.
- Aerospace. This sector has traditionally been engaged with NASA, as a contractor and, more recently, as a partner. Over the years, NASA's push towards commercialization has led to the development of a $100 billion global aerospace industry and to many commercial technologies that have both ground-based and space-directed uses. Although this research was specifically designed to explore non-aerospace applications of microgravity research, we arrived at the conclusion that this is the only sector that could see some value in investing in ISS-based research via Entrepreneurial Offers, and has the technical and logistical know-how to draft such an offer. In particular, this sector may wish to use the ISS as a test-bed for technologies and products to be used in space flight or in ground-based applications. For example, a company may want to test a special radiation-resistant material for space flight, but may also use the same material for radiation shields to be used on Earth.

  This sector is accustomed to working with NASA and to the concept of developing technologies that have space- and earth-based applications. Furthermore, as this program develops, the aerospace sector may be able to facilitate participation by other industry sectors by partnering with them on technologies that have dual applications.

This list of priority sectors is a guideline to focus NASA’s outreach efforts. Advances in microgravity and changes in the economy may make other industry areas more attractive than these, and NASA should remain open to changing its focus as appropriate. Furthermore, CSCs that have made inroads into other industry sectors should continue to build on those contacts and pursue business in those sectors.

Table 8: Summary of Evaluation of Target Industries						
Target Industry	Known microgravity applications	Relevance of microgravity research	Research focus (R&D budget)	Value of consumer support and publicity	Experience with NASA[8]	Other relevant information
Medical Biotech	▪ Growth of macromolecular crystals. ▪ Biochemical separations. ▪ Microgravity changes in cell physiology, proliferation and death, and gene expression—development of tissue cultures. ▪ Biofermentation and secretions. ▪ Biomaterials.	As the sheer number of relevant applications suggests, this sector can be widely impacted by microgravity research. Protein crystal growth and tissue culture growth in particular are "hot" research topics in this industry. Most of these applications are such that single experimental successes in space can yield information that can be easily applied to earth-based research or processes.	This industry is highly competitive and research-focused. *Has the largest R&D budgets (as proportion of revenues). In 2000, research spending approached $16 billion.* IP is the key to market valuation in this sector. In a sense, a company's patents *are* its products.	While few of these companies are currently marketing products directly to consumers, they are moving in that direction so that association with NASA and the publicity it garners for them will be valuable. Also, publicity that makes them noticed by investors is especially valuable to this industry.	This sector has little experience with NASA directly but the CSCs have made some inroads into this industry and have partnered with some of the major players. Generally speaking, interviewees had a "rosy" picture of NASA, although they didn't see its relevance to their industry. This sector is one of the most stringently regulated, and is very wary of government in general (esp. FDA). However, companies do work with academia and so can adapt to non-corporate partners.	This industry is highly competitive and fast-paced. It is a highly consolidated sector. With the exception of the major players, biotech companies are resource-strapped, both in terms of cash, but also in terms of personnel, samples, equipment, etc. Market valuation of these companies is highly volatile and this contributes to the pressure for quick results. A six-month turnaround on a project is regarded as too long.

[8] We are presenting only a very general summary of each industry sector's exposure to NASA and CSC research opportunities. This column is designed to give the reader an idea of how big a splash NASA and/or the CSCs have made in each of these sectors, how familiar these sectors may be with NASA's expertise and processes, and how readily they may see NASA as a research partner.

Table 8: Summary of Evaluation of Target Industries (Cont.)

Target Industry	Known microgravity applications	Relevance of microgravity research	Research focus (R&D budget)	Value of consumer support and publicity	Experience with NASA	Other relevant information
Pharmaceutical	▪ S tudy of microgravity on immune reactions, bone loss, electrolyte regulation, and muscle degeneration processes that mimic disease processes. Developing mechanisms to counter these effects. ▪ D rug testing. ▪ B iosecretions. •	This industry is shifting to the concept of rational drug design, which is based on studies of cell biology and disease processes for target identification and validation. Studies in space can yield information to improve disease models and thus help speed up drug discovery.	New products are critical to survival in this industry. Desired growth rate of 10% can only be maintained by exploring about 42 new drug candidates a year. The average cost of drug development is about $350 M, and the process takes about 12 years. Anything that reduces this time or cost is valuable to this sector.	These companies typically spend hundreds of millions of dollars to differentiate their product and market their drugs. They rely greatly on consumer confidence and goodwill and may be able to use the association with NASA and space research in their marketing.	As with Biotech, the pharmaceutical sector has very little experience with NASA, although the CSCs have made some inroads into this industry and have partnered with some of the major players. Industry personnel have a “rosy” picture of NASA, although they don’t see its relevance to their industry and fear government regulation.	Somewhat more bureaucratic than the medical biotech sector and more beholden to investors. Better established and less strapped for resources. Very competitive; pipeline is secret. Generally, time-to-product is long, even after research successes (due to trials and approval processes). Thus, they are used to looking at longer time frames. Also used to taking risk with product development, since most candidates do fall by the wayside during the drug development process.
Agritech (and other non-medical uses of biotech)	▪ S tudy of plant growth in microravity. ▪ B iofermentation. ▪ P roduction of plant antibodies. ▪ G ene transfer for new crop species.	Growth of cell cultures and harvesting of plant or microorganism metabolic products have great application in a variety of non-medical biotech industries, including agritech (food and nutra-ceuticals) and industrial (waste disposal). The relative advantages of studying gene transfer in space are not established.	Innovation is important to this industry too, but overall research budgets are not as large as the pharma and biotech industries. In the year 1997, the agri-tech industry spent approximately $1 billion.	The major agritech companies need good publicity to counter controversy over genetically modified foods, but NASA should not get embroiled in this controversy. Biofermentation applications for food and industrial products are less controversial.	The CSCs have worked with some highly innovative agritech companies and nonprofit consortia. This industry sector is, however, highly consolidated, and NASA must target the “heavy hitters” such as ConAgra, Monsanto and Dupont if it is to gain mind share as a partner. Some of these companies have collaborated with the CSCs but not in the area of agritech.	The industry is dominated by a handful of large companies. It is stringently regulated by the EPA, the FDA, and the USDA and lobbies heavily to relax this oversight. The time-to-product in this industry is quicker than for medical biotech since clinical trials are not needed.

Table 8: Summary of Evaluation of Target Industries (Cont.)

Target Industry	Known microgravity applications	Relevance of microgravity research	Research focus (R&D budget)	Value of consumer support and publicity	Experience with NASA	Other relevant information
Electronic and Optical components	▪ Study of crystallization processes. ▪ Thin film deposition. ▪ Containerless processing.	Microgravity research is most relevant for the semiconductor market, which is probably the largest single product for this sector. Some work has also been done in the field of thin film deposition that is relevant to the development of LEDs. Materials with unique conductive properties may be used in electronic circuits.	This is a research-driven industry—high R&D budgets, rapid advances. Pressure to make faster, smaller, better products. The semiconductor industry is driven to double microprocessor efficiency every 18 months. But R&D funds are greatly reduced in light of current economic setback and market uncertainty. The semiconductor sector is now seeing a sharp decline in revenue.	Some of the major companies in this area (e.g., Intel, IBM) have embarked on direct-to-consumer advertising, but mostly this is a B-to-B industry.	Historically, smaller companies in this sector have worked with NASA primarily through tech transfer/SBIR mechanisms. While key scietntists and decision-makers within this sector probably appreciate NASA's traditional role in supporting technological advances, they may be less supportive of NASA's current push to seek private sector investment in space research.	The rapid pace of innovation makes it unsuitable for long-term research projects. Money for basic research is especially reduced in the current economic environment.
Metals & Metal Products	▪ Better models for fluid processes. ▪ Measures of fluid properties to improve models for industrial processes such as solidification design. ▪ Development of new materials (e.g. alloys of immiscible fluids, metallic glasses with particulates). ▪ Containerless processing.	This industry stands to gain most directly and immediately from basic research on fluid processes. This information can be directly applied to models and production processes on earth.	This is a highly scientific industry, with at least some companies conducting extensive research to develop new or customized products. This segment is likely to benefit from research on new materials and alloys. For the industry in general, though, innovation may be more focused on incremental process improvements rather than dramatic advances. They will be interested in basic studies that can lead to increases in efficiency.	Remains a B-to-B industry. Has not reached out to consumers.	This sector has not traditionally seen itself as a candidate for "high-tech" research with NASA. CSCs are, however, beginning to work with these companies, particularly with those that manufacture specialty materials or are engaged in complex casting processes. NASA's recent partnerships with large, established companies in this sector are likely to enhance its presence in this sector.	The specialty metal sector has been largely a locally and regionally concentrated, unconsolidated industry, but is expected to see rapid consolidation in response to the cost pressures imposed by its primary market—the mature and consolidated automotive industry.

Table 8: Summary of Evaluation of Target Industries (Cont.)

Target Industry	Known microgravity applications	Relevance of microgravity research	Research focus (R&D budget)	Value of consumer support and publicity	Experience with NASA	Other relevant information
Heavy machinery and automotives	▪ Combustion processes. ▪ Catalytic processes. ▪ Fuel purification (chemical separation systems). ▪ New materials (lighter, stronger). ▪ Crystals (for drill bits, etc.). ▪ Improvements in casting processes.	This industry is impacted by microgravity research in several different ways. Most of them call for changes in the manufacturing process, and are likely to lead to more efficient production mechanisms.	This is an industry that conducts long-term research and has huge research budgets. However, it tends to demand proven concepts and may rely on purchasing pre-commercial research rather than conducting basic research.	The automotive industry is clearly consumer-focused and can use space research in marketing and differentiating products. Other segments of this sector rely on B-to-B marketing, but many are large enough to value name recognition among consumers.	Some of these companies have worked with NASA or its aerospace contractors. Several of these companies have also worked with the CSCs on innovations designed for space exploration and for use on Earth. This sector also overlaps somewhat with the aerospace industry, which has been among the first sectors to benefit from space commerce.	These are large companies with worldwide markets and budgets, and have the resources to invest in long-term projects. This industry is under pressure to increase fuel efficiencies, and is a large market for materials with improved structural properties.
Environmental Sciences	Air and water filtration & recycling. Solid waste disposal. Cleaner, cheaper energy (alternative sources).	Many of NASA's efforts towards space exploration are focused on sustaining human life more efficiently, and that is what this industry is about.	This industry is future-oriented and does conduct research with long-term applications in mind.	Most companies in this sector are too small for mass consumer marketing, but specific products can be marketed with reference to NASA.	This sector is relatively small, young and unconsolidated. Many of the most cutting-edge companies have some experience with CSCs. Some have also worked directly with NASA or its aerospace contractors, mostly through grants or as subcontractors.	Many companies in this sector have small budgets, but industry can be developed through NASA grants and contracts. This sector has potential for spin-offs and spin-ons along with cooperative research.
Chemicals	Microgravity studies of colloidal states and other fluid processes may be relevant for manufacturing specialty chemicals. Research on thin films and chemical separation is useful for purification and filtration.	Microgravity research on colloidal states and polymers has most application for the production of specialty chemicals (about 6% of the chemicals market). Growth of inorganic industrial crystals (like zeolytes) may not have great utility since ground-based processes are adequate for industrial applications.	This industry is focused on more practical applications.	Most of the specialty chemicals manufacturers market to businesses. Very few industrial giants in this sector communicate directly with consumers.	The chemicals sector in general is not heavily engaged with NASA, although certain leading companies in the specialty chemicals sector may have some exposure to NASA's research on crystal growth, chemical separation and thin film transfer processes.	Relative to commodity chemicals, the market for specialty chemicals is smaller and not as mature, but it has seen more rapid market growth. Flexibility and customization are critical for specialty chemicals manufacturers.

Table 8: Summary of Evaluation of Target Industries (Cont.)						
Target Industry	Known microgravity applications	Relevance of microgravity research	Research focus (R&D budget)	Value of consumer support and publicity	Experience with NASA	Other relevant information
Ceramics	▪ The study of ceramics has been judged a lower priority area for microgravity research because it is less impacted by fluid processes. However, some industrial processes such as powder processing stand to benefit from containerless processing studies in microgravity.	The relevance of microgravity research to this sector is limited to the advanced ceramics sector, which accounts for about 16% of the market. The range of microgravity applications for this sector is somewhat limited.	Research in this industry is focused on improving reliability of finished products and the cost/benefit ratio of ceramic components. Improvements are occurring in the areas of powder processing, machining, non-destructive evaluation, and product standardization.	This is largely a B-to-B sector. Very few ceramics manufacturers and innovators publicize their accomplishments to consumers.	The ceramics sector in general is not heavily engaged with NASA, although certain leading companies in the field of advanced ceramics may have worked with NASA in the past as vendors.	
Aerospace	▪ Test-bed for space applications (with uses on Earth).	This industry can benefit from virtually all of NASA's basic and applied research in the fields of engineering and Life & Physical Sciences.	The aerospace industry is closely tied to defense and space research. This industry has large research budgets, although often these may be derived from government contracts or grants.	The competition within this sector is intense and it has come to the fore of the public's mind in recent months. Thus, even though this sector rarely conducts business directly with consumers, it may be sensitive to consumer opinion.	Extensive – which is good because they understand NASA's protocols well, but bad because they may have been "burned" by these protocols.	This may be the only industry that is "ripe" for EOs. It has been nourished and guided by NASA contracts, and the same mechanism can be used to focus this industry on earth-based applications.

Chapter 4: Audience Analysis

In this section, we describe the key findings from interviews conducted with NASA & CSC members, as well as interviews with members of target industries (see Appendix A for a list of interviewees). We have also included the results of a survey of businesses conducted by the European Space Agency (ESA).[10]

Main Findings from Interviews with NASA Staff

Procedural Issues

I think right now the access to space and reliability of the flight rate is the key limiting factor.
NASA staff member

- Delays in space flight opportunities were identified as the main barrier to participation by NASA and CSC staff engaged in outreach to industry or work with industry partners. CSC members in particular expressed frustration with the uncertainty of flight schedules (e.g., manifested payloads can be bumped off the flight at the last minute) and the apparent arbitrariness of the decisions regarding what payloads will be manifested and flown. This makes it difficult for them to plan a program of study with their industry partners and to deliver results as promised. Some CSCs said they had lost industry partners who were not flown as promised. Some NASA officials suggested that it is important for NASA to be realistic about what they can deliver to industry partners and the timeframe in which they can do this.

- Among NASA staff itself, there seems to be a general confusion about how flight payloads are manifested and how final decisions are made. Most people recognized that current shuttle flight opportunities for research are inadequate and severely limit research progress. Most respondents believed that this will improve once ISS construction is completed. However, there was disagreement about how much this can be improved. Some respondents felt that NASA must be able to guarantee space flight within six months and others felt that safety necessitated a slower process.

- There was also some confusion within NASA about who is responsible for "booking" commercial research space aboard the space station and how much space is still available. One respondent indicated that industry's 30% rack allocation for the space station is already filled to capacity.

Communication and Outreach

The quality of life for people will change because of the research that people get off the station.
NASA staff member

- Most of the NASA personnel we interviewed do see space commerce as the next logical step to conquering space—the final frontier. Many at NASA used a *Wild West* analogy when discussing space, and likened NASA's current role to that of the government building roads, railways and other infrastructure for the population and development of the West at the turn of the last century. They believe it is the next frontier to be tamed and that there is huge potential in space that will revolutionize human existence on Earth. Some specifically mentioned that understanding microgravity and how to use it would lead to great advancements as well.

- Several staff members identified the following flaws in NASA's outreach efforts:
    - NASA does not deliver a consistent, coordinated message to the public. Although some NASA staffers are trained in media relations, this training is more about format and style, rather than content. As a result, NASA officials do not have a consistent message platform to guide their public statements.
    - NASA's ability to advertise itself to the public is limited and this translates into NASA keeping to a strictly fact-based or education-oriented message. As a result, NASA culture leans toward delivering content in uninteresting ways. Many outreach staffers noted that NASA focuses on telling the public what is happening at NASA, without any explanation of why it's happening, or why it is important (to the public).
    - NASA tends to "talk a lot to the choir" and needs to structure messages to make them relevant to a wider audience.

NASA culture has often emphasized communicating in a dull way. It has been hard for people to break this and be more human. The Mars lander was a significant break-through because scientists were visibly very excited about what was happening and did things to make the project more human—like naming rocks for cartoon characters.
NASA staff member

- Another major barrier to effective outreach and external communications is the lack of internal communication systems. At the start of this project, one NASA staffer said that we would soon find out that "there are many NASAs." At the time, we did not realize how true this statement is. All of the people we interviewed were very knowledgeable about their own work but were limited in their knowledge of NASA's programs, processes and achievements outside of their own work. Unfortunately, this lack of knowledge and communication often leads to inefficiency and duplication of efforts. It also means it is difficult for people to refer someone to the appropriate Code or individual who might be better able to provide assistance.

- Outreach people at NASA also discussed their inability to publicize NASA's achievements appropriately because they do not hear of them in time and sometimes not at all. This seems to be true for all of NASA's research, but is particularly so for commercial research conducted via the CSCs. Even if NASA outreach staff do try to develop a story or event with a magazine or a community partner, their efforts are stymied by their inability to access more information or speak with the people who are directly involved in the research.

- Two interviewees identified a special problem related to media outreach focused on the ISS. In order to justify the expense associated with this venture, NASA initially made unrealistic promises to Congress and the public about how soon the station will be built and what it will achieve. These interviewees commented that this initial “hype” has made it difficult to get the media to appreciate what the space station *has* achieved, since all advances compare unfavorably with the initial expectations. They noted that there is an informed and dedicated corps of journalists who have been following the space station since its conception and are familiar with its history and development. Understandably, many of them are skeptical of NASA’s claims of the benefits the ISS will bring to the nation. Another interviewee noted that since the ISS is now in orbit its existence is routine and perceived as unnewsworthy.

- Staffers in several areas commented that NASA enjoys great name recognition and an extremely positive image among the general public. Those in outreach said astronauts are still role models that fill children and their grandparents alike with wonder and awe, and images of far-off planets and the promise of reaching these places still capture the public’s imagination. NASA also has a reputation for excellence and achievement, although this is diminished by the recent negative press on budget overruns and shelved projects.

- NASA staff noted that while NASA’s achievements in space exploration are a source of pride for the nation, actual knowledge about NASA and its activities is very low. Few people pay attention to when Shuttle launches occur and while most people know that there is a space station very few people realize it already exists and has astronauts on board continuously. More specifically, staffers noted that even fewer people understand that NASA does research that has application and value on Earth, or that technological advances sparked by NASA’s research have already brought great benefits to the country’s economy and its citizens’ lives.

The challenge from a marketing standpoint is that people don’t see the kinds of research going on or they don’t feel that it has any real bearing in their lives. So it’s a schizophrenic situation where there is a general appreciation for the majesty of a shuttle launch but beyond that most people don’t have any clue about what that means, and if it has any bearing in their lives. And most people don’t think it does.

NASA staff member

Knowledge and Opinions of Industry Audiences

The only published consumer research we were able to locate on this topic is a series of interviews with industry executives conducted by the European Space Agency.[10] The main conclusions from this study are as follows:

- Industry scientists believe that participating in microgravity research could be an advantage but realize that the focus should be on fundamental research that might lead to better understanding of basic processes and phenomena.

When we look at the cost of achieving or improving technology it isn't just the cash outlay. It is also the ability to manage it internally; the people allocation and project management are major factors.
Pharmaceutical scientist

- Industry has three primary concerns about space research: potential application of results is unclear, requirements for conducting microgravity research are incompatible with terrestrial experimentation, and cost in terms of flight and experimentation preparation are too high.

- Because microgravity research is best suited to answering basic science questions, industry professionals believe it should be conducted by academic researchers using public funds. Microgravity research is a useful new tool but does not appear to solve any of the problems currently faced by industry.

- To involve industry in microgravity research, research needs of specific individual companies must be addressed.

Our interviews confirmed many of these findings for U.S. industry. In addition, we found that:

Microgravity Research Applications

There are technologies that can take advantage of microgravity but I don't think most people have even thought about it.
Biotech scientist

- Familiarity with microgravity research is low. Many in the biotech and materials industries have heard of microgravity research and read something about it, typically in a general science publication like *Discover* magazine, but few know much about it to any great detail. More importantly, they do not see how this might apply to their industry.

- When some of the applications of microgravity research were explained to respondents, they were able to see its relevance to their field. Many biotech industry professionals were sufficiently intrigued during the interviews to invite a more detailed presentation to relevant decision-makers at their company.

Initially I just couldn't see what the commercial application would be [of microgravity research]. But once you start going through all the specifics and what's been shown then you see that this is interesting.
Pharmaceutical scientist

- Some applications were thought to be more useful than others. For example, respondents from the biotech industry felt that gene transfer on Earth has become quite efficient, and scientists are unlikely to want to pursue this in space. Even if the odds of successful gene expression are somewhat higher in space, the fact that you can do so many more experiments on Earth makes it more economical and efficient to pursue this research terrestrially.

- In the field of materials sciences, industry respondents identified improvements in inorganic crystal growth processes as an important objective for the semiconductor industry. Microgravity research was also believed to be useful for certain kinds of materials, such as those that are "sticky" or where sample contamination or degradation due to handling or container-induced defects is a concern.

- Crew time may be an issue for materials research since many experiments require careful monitoring. As one respondent said regarding thin films, "This is an area where a lot of human feedback is needed so that even though the process itself is automated you can make sure there isn't error and compensate for any errors that do occur."

Decision-making Processes

- Decision making for research projects usually follows a *bottom-up process*: A senior scientist will recommend a project to a higher executive, who gives approval and funding for research. It is very important for the scientist to be able to understand and explain the scientific benefit to this decision maker. Occasionally, industry partnerships may come about via a *top-down process* where the opportunity comes to the attention of a senior executive, who will then ask his/her scientific staff to explore the potential benefits. In either case, both scientists and senior-level executives need to be persuaded of the benefits of this research, the former of its scientific viability and value, the latter of its financial or strategic benefit to the company. This points to the need to address two distinct industry audiences—scientists and executives.

If the scientists are excited by it then our boss usually knows how to work the system to make things happen.
Pharmaceutical Scientist

- These industries, which are on the cutting edge of science, are not risk-averse, and recognize that all innovation involves some degree of risk. As one respondent stated "If they want to get into a market they need to be a continuous pioneer." However, this is tempered by an overarching concern for the bottom line. Companies will undertake research if they can see some kind of financial benefit for doing so. This benefit doesn't have to be short-term; forecasting a long-term financial return could be sufficient. But industry scientists and executives do need to be able to clearly visualize the path the research will take and the benefits it could yield.

- Protecting intellectual property is critical to industry participants, both in terms of maintaining secrecy about products or processes and in terms of owning research outcomes. Industry needs assurances that the confidentiality of the information they provide to NASA is maintained, and that NASA is willing to work out agreements in which industry partners maintain exclusive rights to research outcomes.

The research isn't just driven by the buzz of the science alone. We are operating in a business environment. If the gains of a microgravity environment—the benefits of this new technology compared to business as usual—don't have a fairly decent return, then it won't go forward.
Pharmaceutical scientist

Barriers and Motivators

If I can cut the antibody production cycle down to a one-month versus a six-month cycle—made compound, got it tested, got the information back, made more compound—then that would be great. The six-month cycle is not do able. You're dead.
Pharmaceutical scientist

- Timing for conducting microgravity research is a critical barrier. Companies want to have a fast turnaround on research. The shortest window possible is desired; a year may be too slow. For example, the semi-conductor industry aims to double the efficiency of its products every 18 months. In such an environment, a research project that takes 18 months to process is not likely to be perceived as a good investment. Similarly, one interviewee noted that the Biotech industry is fiercely competitive and a fast turnaround time is imperative. Even a six-month research cycle is too slow for a cutting edge company's survival. However, larger, more established biotech firms may be willing to invest in some longer-term projects.

- In the current environment of economic uncertainty and severe cutbacks, lack of adequate resources for microgravity research is likely to be a critical barrier. Not only were interviewees concerned about the financial cost of conducting this research, they also expressed reservations regarding their ability to staff and manage such a research project or access the appropriate hardware and materials.

Right now, the bottom line is key. People are very concerned about the bottom line and trying not to do layoffs. A year ago they were willing to do this kind of research, but right now not so much.
Semi-conductor executive

- Tangible results from prior research are most likely to persuade corporate scientists to conduct and promote such research in their companies. This means not just showing that a certain outcome resulted from an experiment but being able to prove that this finding is valid and replicable, and provides new or even groundbreaking insights.

- Overall, industry members' perception of NASA is very positive. However, their view of NASA is based on a lay perspective rather than their experience as scientists and professionals. Many subjects specifically mentioned things like visiting the NASA website, watching Shuttle launches, or having pictures of space in their offices/homes. Many of them grew up in the days of the Apollo excitement and took a keen interest in space science. Overall, industry members have a fondness for NASA that derives from NASA's efforts in space exploration rather than from its scientific expertise or commercial opportunities. Nonetheless, many in industry said they would welcome the opportunity to work with NASA.

I'm there throwing kudos when the Shuttle blasts off. I've got a 12-inch telescope at my house. It's good stuff. I love it.
Pharmaceutical scientist

- Some of these industry executives who had worked closely with NASA in the past complained about NASA's general inability to stick with flight schedules and budgets, and the fact that there is no recourse for companies or individuals who incur losses due to delays or mistakes on NASA's part.

Chapter 5: Communication Strategy

Definition of NASA's Offer

Our first step in developing a communication strategy was to identify the key components of the "offer" that NASA is making to industry partners. NASA reports characterize the ISS as a unique laboratory that offers long-term, human-tended microgravity and vacuum environments, and a unique vantage point to view and photograph the Earth and space. Of these three benefits—microgravity, vacuum and vantage position—it is microgravity that is most unique to the ISS and most difficult to replicate by other means. Thus, long-term access to a human-tended microgravity environment is the main benefit of doing research aboard the space station.

In evaluating this offer from the audience's perspective, however, we realized that few people appreciate the importance of microgravity research, let alone the benefits of conducting this research aboard the space station (which offers the best available microgravity environment). NASA's "competition" in this effort is not other research facilities but other kinds of research. Our task, then, is not simply to promote the benefits of the space station as a unique research environment, but to increase awareness of the benefits of microgravity research as a discipline. In marketing terms, our task is to create and define a new market category and to create a market demand for this category.

Key Shaping Factor: The State of Microgravity Research

The most important factor in shaping our communication strategy is the current state of microgravity research. As discussed earlier in this report, the field of microgravity research is too new and too wide to identify the most promising areas for development. Furthermore, microgravity research offers few immediate "solutions" to the problems faced by industry; instead it invites a fresh perspective on these problems and generates new questions that could lead to a greater understanding of the underlying phenomena. The field is still in the early phases of identifying, replicating, describing and categorizing phenomena, and little progress has been made towards developing explanatory models or hypotheses. This lack of data makes it difficult for companies to foresee a clear pathway or program of study that can lead to specific discoveries.

The complexity and expense of microgravity research make it difficult for this discipline to compete with Earth-based programs of study. While the success rate of certain studies or the accuracy of certain measurements is likely to be higher in microgravity, scientists are aware that they can conduct many more experiments on Earth more quickly, so that the overall chance of making a significant discovery is greater.

Finally, the current economic downturn is likely to strain available research resources. Many industries are coping with more immediate stressors and will be less likely to give NASA's offer the time, attention, and resources it merits. Similarly, the public's attention is also diverted to more immediate issues such as national security. Overall, this is an unfavorable media and industry environment for this communication initiative. This factor plays an important role in our recommendations for industry audiences as well as the overall program implementation (see Chapter 6 for details).

The Benefits of the Offer

Microgravity research is a brand new discipline that holds the promise of significant advances in the next few decades. The long-term benefits of this research include:

- Improvements in current production processes based on knowledge from space.
- Development of new products and processes based on ideas generated from space research.
- Reduction in time-to-market based on space research results.
- Reduction in product development costs.
- Development of new products that are processed in space and returned to Earth.

However, most industry decisions are more influenced by the short-term outlook than by the long-term benefits of a course of action. Corporations are more likely to co-opt and advance technologies that are closer to fruition, so that they can expect quicker returns on their investment and can be more certain of the results. Furthermore, many high-tech industries are used to a tech-transfer model where the more fundamental research is conducted by government or academia, and industry purchases or licenses the rights to develop the product and take it to market.

Industry decisions usually involve a risk/cost trade-off: they can either make a relatively risky but inexpensive purchase of a technology in its early stages, or minimize risk by purchasing or licensing a relatively developed technology even though they have to pay more for it. Unfortunately, in difficult economic times, corporations are less likely to take on risky enterprises.

To engage industry in microgravity research in this early phase, NASA needs to highlight the immediate and short-term benefits of commercial participation in this research. In the short term, this program offers:

- A fresh look at the problems that industries have been grappling with. The manipulation of gravity as an experimental variable introduces a new dimension to scientific inquiry. This is likely to appeal to corporate scientists' spirit of inquiry and exploration.
- Participation in forging a new discipline of study, that is likely to yield significant benefits in the future. Through their early participation, companies can gain a strategic and competitive advantage over their competitors and be in a better position to use the research as it is generated.
- Cost-leveraging with NASA.
- Access to expertise of NASA scientists and academicians (through the CSCs).
    - Access to CSC research resources through partnerships
- A long-term collaborative program of study that yields important discoveries and advances, some of which may have immediate application.
- Prestige and visibility through association with NASA and the ISS.

The Basic Strategy

The strategy of this program is driven by our need to highlight the short-term benefits of participating in microgravity research, most notably, the strategic advantage and cost leveraging gained by early participation in this field, and the opportunity to be perceived as an innovative, progressive industry leader within the industry and among the public. Our strategy is to:

- Widen awareness and perceived relevance of microgravity research among public and industry audiences. This includes bringing NASA's research out of the "aerospace world" into more industry sectors and into the mainstream media and public discussion forums.
- Create a public and media environment that values industry participation in this venture. This is critical for validating the short-term public relations and image-building benefits that we promise companies that choose to participate in this venture.
- Associate industry participation with valued attributes such as innovation and leadership. Microgravity research is truly a "new frontier" of great potential and great uncertainty. Nonetheless, Americans have always understood that innovation and leadership require a certain tolerance for risk-taking, and they value such qualities in corporations.
- Position NASA's offer to highlight benefits while minimizing costs. One of the greatest benefits to participating in microgravity research in this early stage is that industry can leverage both costs and expertise through collaborative research with the CSCs.

Target Audiences

The primary target audiences for this effort are target industry staffers—scientists or executives—who can either decide to enter into a research partnership with NASA or can initiate or advocate for this participation. Our research shows that such a decision may be initiated either by scientists or by executives who are intrigued by the possibilities of this research, but it usually has to be approved by a mid- to senior-level executive.

In addition, industry business and thought leaders often set the tone and agenda for their industry sector and have an important impact on the R&D and other strategic decisions of individual companies. Thus, we propose the following levels of outreach to industry audiences:

1. General industry level outreach to target industries.
2. Outreach to specific scientists or workgroups within target industries.
3. Outreach to industry business and thought leaders, including CEOs, influential analysts, and heads of trade associations or think tanks.

Given that microgravity research is unlikely to yield immediate and certain financial returns for participating corporations, enhancing the strategic and public relations appeal of conducting this research with NASA is a critical component of our communication strategy.

This can be achieved by raising the visibility and status of this program *among the general public, and more specifically, among opinion leaders*, so that a corporation can create confidence and goodwill among its constituents through participating in this research. Thus, we have identified a fourth audience for this campaign:

4. The Influential Public, consisting of educated and professional adults ages 30-65, particularly people who are oriented towards technological advances and may be considered opinion leaders in this area.[9]

How it works together

Table 9 illustrates the communication objectives and messages for each of the four program audiences. The program is based on the premise that, given the current state of microgravity science and the economy, the barriers to participation in microgravity research (i.e., insufficient data, uncertainty of flight opportunities, and long-term commitment of time and resources) are likely to outweigh the long-term promise of this research. Except in a few special cases, corporations are unlikely to see any *immediate* and direct return on their investment in microgravity research, although the long-term potential for benefit is very great. Furthermore, this field does not hold sufficient promise at the moment to divert funds from ongoing ground-based research.

We therefore recommend that the scientific, strategic, and public relations benefits of engaging in microgravity research at this early stage of the field's development should be emphasized in all communications. We wish to promote this research to corporations because it allows them to:

- Be pioneers in forging a new discipline (scientific advantage).
- Serve as leaders in their industry, and be better positioned to take advantage of research findings as they become available (strategic advantage).
- Position themselves favorably with their stakeholders – customers, employees, and shareholders (public relations advantage).

The main objective of the communication with the influential public is to educate them about the value and wide applicability of research aboard the ISS, and to create an environment where participation in this research by corporations is valued by their shareholders and customers. The communication with CEOs and business leaders is intended to further raise the visibility and prestige of this effort, affirming that industry leaders recognize the long-term potential and value of this research. It also serves to get the business community more engaged in this initiative, which has hitherto been directed by the scientific community.

In this more favorable social and media environment, communications directed at the targeted industries, or specific scientists or workgroups which focus on the relevance of this research for their needs, will be received more favorably. Furthermore, interested scientists or executives will be able to marshal internal support for such projects more easily, leading to quicker action on these leads.

The messages for each audience (see Table 9) reflect differences in the appropriate appeals and message complexity for these audiences. Our research suggests that the public has little knowledge or awareness of microgravity research, of NASA's contribution to earth-directed applied research, or of the use of ISS for earth-directed research. The messages for the public

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[9] This group represents the focus of our outreach efforts. Although this audience could be more broadly construed—such as including younger high-tech professionals or high-tech savvy retirees—we believe narrower definitions of a target audience are more effective.

are, therefore, rather general and intentionally simple. They are intended to increase the perceived relevance and value of space-based research, and of NASA's engagement and expertise in developing technologies that directly affect people's lives. They build upon two key motivators – the public's pride in space flight and in NASA and the public's interest in scientific advances, particularly in the field of health and the environment. Positioning microgravity research as a frontier to be explored and developed is also likely to spark interest in the media and the public.

Outside of the aerospace industry, most industries are also largely unaware that they can benefit from microgravity research. The communication with this audience is more focused on the specific research applications that are relevant to their industry, and publicity on how other companies have benefited from joint programs of study with NASA. The main objective is to help industry professionals understand how their industry may be impacted by microgravity research and how other companies are already taking advantage of this opportunity.

Corporate scientists, like scientists in academia or government, value exploration, discovery and serendipity. Thus messages directed to them should highlight the opportunity to make new discoveries using gravity as an experimental variable. Scientists are also data-driven in their thinking and highly wary of exaggeration. Thus these messages should be data-driven and will focus on establishing the legitimacy of microgravity research as a new scientific discipline. They should discuss potential learnings and findings without making unrealistic leaps to practical applications of these findings.

Finally, communication with business and thought leaders will appeal to their desire to be forward-thinking leaders for their industry. Participating CEOs and thought leaders will be invited to join membership to an elite community (e.g., industry panel) that is shaping this initiative on the cutting edge of technology and commercial enterprise. All communication with this audience will reflect an appropriate degree of exclusivity and will allow the target audience to benefit from networking and public relations opportunities.

Table 9: Summary of Communication Strategy

<table>
<tr><th></th><th>Audiences</th><th>Communication Objectives</th><th>Motivators</th></tr>
<tr><td rowspan="4">Goals of the Communication

Raise awareness of the benefits of microgravity research, especially on the International Space Station

Raise awareness of NASA’s commercial research program

Attract private sector interest in microgravity research with NASA

Strategy

Widen awareness and perceived relevance of microgravity research among public and industry audiences

Create a public and media environment that values industry participation in this venture

Associate industry participation with valued attributes such as innovation and leadership

Position NASA’s offer to highlight benefits while minimizing costs</td><td>Influential Public</td><td>Increase awareness and perceived relevance of space-based research, particularly aboard the ISS

Increase awareness and perceived relevance of NASA’s technical and research expertise, particularly outside of space exploration

Generate awareness of space commerce and NASA partnership opportunity

Counter negative publicity about ISS</td><td>National pride in NASA

Fondness for leadership in space exploration (Space Nut factor)

Interest in scientific advances in health and environment</td></tr>
<tr><td>Industry Executives and Leaders</td><td>Engage senior executives to participate in and guide NASA’s commercialization venture

Encourage them to promote space commerce to media and within their industry

Encourage them to take the lead on commercial space research for their sector</td><td>Desire for their company to be strategically positioned at the cutting edge of science

Desire to be personally seen as industry influentials and leaders, chosen to represent their industry sector in this effort

Media/publicity opportunities

Networking opportunities; keeping a finger on the pulse of the industry</td></tr>
<tr><td>Industry (in general)</td><td>Increase awareness of microgravity research applications for each industry sector

Increase perceived value of researcher partnership with NASA

Identify appropriate contacts for follow-up</td><td>Scientific interest/discovery

Tangible results (not necessarily products but answers to questions)

Affiliation with NASA/space-based research

Access to NASA and academic expertise at low cost</td></tr>
<tr><td>Corporate Scientists</td><td>Introduce microgravity research to appropriate scientists; generate interest

Increase credibility and perceived applicability of microgravity research; engage scientists in discussion of possibilities

Persuade them to suggest this research for their company or support it in discus-sions with other scientists or managers</td><td>Desire to conduct cutting edge research

Scientific curiosity and value of serendipitous discoveries

Enthusiasm for space exploration and “cool” technologies

Enthusiasm of working with NASA</td></tr>
</table>

Table 9: Summary of Communication Strategy (Cont.)

Barriers	Messages
Do not see relevance of space-based research to self, society and nation In tight economy ISS may not be much of a priority Negative publicity about ISS may make public reluctant to support and/or fund space-based research	NASA's research has a track record of providing health and environmental benefits to consumers Space-based research represents an important new frontier for science; making investments now will facilitate critical breakthroughs NASA is developing a new model for space-based research that is based on collaborative partnerships among businesses, government and academia
Lack of understanding regarding benefits of basic research Insufficient "buzz" about microgravity research to make participation worthwhile	NASA is tapping industry leaders to play a vital role in shaping space commerce and research By participating with NASA, you can represent your industry's interests and help ensure that space-based research initiatives meet your industry's needs Organizations that get in on the ground floor by participating with NASA now have the greatest opportunity to benefit from NASA's expertise and commitment to cost-sharing
Insufficient data to direct research, identify key applications Uncertainty and delay in flight schedules Insufficient human and material resources to devote to project Incompatibility and competition with existing research projects	Microgravity research will help your industry develop better and more efficient products and processes (validated with examples of research and their application) Organizations that get in on the ground floor by participating with NASA now have the greatest opportunity to benefit from NASA's expertise and commitment to cost-sharing Other companies are already participating and seeing results
Need better data to convince them of validity of findings Are stretched for time and resources Can't make ultimate decision to fund research	Manipulating gravity as a variable allows for a fresh approach and perspective on research questions Space-based research is a new frontier for science. Your research will be laying the groundwork for critical breakthroughs You can collaborate with the best minds in NASA and academia and benefit from their expertise

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Chapter 6: Program Implementation

This chapter presents communication guidelines and details the implementation of our communication program.

General Communication Guidelines

The following recommendations are general guidelines that apply to all of NASA's communication efforts across all four target audiences. They form the basis for the communication program outlined later in this chapter.

Proactive Media Outreach

To date, NASA's media efforts have been largely reactive; press releases are issued or press conferences arranged largely *in response to* newsworthy events or specific queries from media persons. This approach is unlikely to be adequate for promoting commercial microgravity research. While scientific breakthroughs are newsworthy and should be publicized, science does not generally advance by leaps and bounds but by slow and meticulous progression. A considerable portion of scientific research involves tedious replication, clarification, and furtherance of prior studies, and, unfortunately, this laborious process of scientific investigation does not make for front-page news. In fact, space flight itself has become routinized to some extent, so that shuttle launches and other space excursions do not command as much media attention as they once did.

To maintain microgravity research in the public eye, NASA must work diligently to promote the process of scientific investigation in microgravity, the uniqueness of the ISS as a research laboratory, and the relevance and potential of simple, everyday research results. From a communication standpoint, this calls for pro-active media outreach, *where story ideas are developed and actively pitched to relevant media outlets*, and all opportunities to tie microgravity research in with other stories and events are used to the fullest.

Outreach to Inform *and* Educate the Media and the Public

For a topic that is as new and novel as space-based microgravity research, the media outreach process must be both informational and educational. As noted above, NASA is often reactive in its dealings with the mass media. Too often, NASA focuses on the "what" of a story (i.e., what took place) rather than the "why" of a story (i.e., why an event matters). NASA must make a greater effort to help the media to "make sense" of information and understand its implications and significance. Thus, all communications must focus on the "why" of the story, i.e., why an event, activity, achievement, or discovery is important, not only with reference to NASA's mission and objectives, but from the public's point of view. This is critical in order for the media to understand why they should cover a story and in what context to present it, and for them to be able to convey the significance of NASA's news to the public. NASA should be proactive not just in developing story ideas for the media but in educating and engaging the media, regarding them as an ally to carry its messages to the public.

Furthermore, whenever possible, the importance or significance of the event should be linked with people's everyday lives here on Earth. NASA must try to show how their research can and does affect ordinary people's lives. In light of the current social and economic environment, space exploration and scientific advances for their own sake are less likely to be valued by the public than they were in the more heady and "bullish" environment of the late 1990s. Stories that can show how NASA is serving the general public are likely to be better received, both by the public and the media.

We recommend that NASA take an approach that is better characterized as media outreach and education, rather than the traditional public affairs strategy of making information available via press releases or press conferences. It requires engaging the media in an educational and interactive way, careful cultivation of long-lead stories by providing background information, interviews, and access to materials, and generally engaging in a partnership with the media writer or producer to develop the story. The goal of this effort is not the kind of "news story" that is generated by an event and described in a press release; instead it is a feature article that reports on the past, present and future of an enterprise, includes diverse points of view (say, from NASA spokespersons and industry sources), and therefore, both teaches and informs the public.

Consistent and Converging Messages in Multiple Channels

Public communication is most effective when target audience members are exposed to a consistent message via various mass and interpersonal media channels. Once again, this implies that NASA must conduct media outreach strategically and proactively to make sure its issues receive coverage in the desired media, and that the messages in different media are consistent. All of NASA's communication regarding commercial microgravity research should tie in with the themes of the message platform for the target audience.

Focus on Earned Media

To date, NASA has promoted its commercial microgravity research program primarily through materials distributed at trade shows. The program has also received some coverage in aerospace trade publications, but a rough audit of NASA's news coverage in mainstream publications had very little mention of research that is applicable to biotech, agritech, or materials and processes, and virtually no mention of NASA's efforts to engage industries in these sectors. Media coverage in mass print publications (newspapers and magazines) will help raise the visibility and value of this enterprise. Widening coverage in trade publications (other than aerospace) will also help towards this goal.

Media coverage for an issue can be generated in a number of ways, including orchestrating newsworthy events, linking that issue to existing news or newsworthy events, and discovering and promoting a fresh angle or perspective on an issue. All of these will be used in generating media coverage for NASA's commercial microgravity program.

Targeted Materials

We have set different communication objectives for each of the target audiences (see Table 8 for details). These audiences also vary with respect to their orientation and level of awareness, level of scientific sophistication, and motivators and barriers. Thus, we have crafted different messages for each of the target audiences, in which different benefits of the program will be emphasized.

The communication materials developed for each audience should therefore vary in their content, tone, and level of scientific complexity. Materials should be designed to answer the questions that each audience is likely to have in a way that they can understand. In trying to develop materials effective for audiences as diverse as scientists and the lay public, NASA runs the risk of reaching neither audience; the materials will read as too complex for the public and too "dumbed down" for scientists.

Focus on Customer Satisfaction and Retention

NASA needs to adopt a customer-focused orientation in its dealings with industry partners, and needs to communicate this to industry partners through both actions and words. While this recommendation does not lie strictly within the realm of communication, we believe it is critical to the success and sustainability of the commercial space program. Initial communication and promotional materials can induce industry partners to investigate this opportunity, and, perhaps, even to try it. But to convert these initial contacts into meaningful, long-lasting, mutually beneficial relationships, NASA needs to continually convey to partners that their contribution is needed and valued. Furthermore, NASA's current industry partners can be its best ambassadors or its worst critics, and their recommendations or criticisms might well "make" or "break" the growth of this program. Although creating new partnerships is important, it is even more important to develop and nurture positive working relationships with existing partners.

NASA's partnerships with industry will be put to the test in this difficult enterprise. ISS construction will not be completed until at least 2004 and construction-related payloads carried by the Shuttle are likely to have preference over research payloads. In the short run this means substantial lag time in getting research payloads manifested and/or having payloads cancelled or delayed. These delays and cancellations are likely to frustrate industry partners, but most relationships can withstand such strains provided the partners believe that NASA is making a good faith effort to understand them and accommodate their needs. In addition, NASA can forge good working relationships by:

- Developing a clear list of priorities and decision-making criteria so decisions about what flies and what gets "bumped off" do not appear to be arbitrary and/or political.
- Setting up realistic expectations and not overpromising.
- Being honest and open in communication with partners, especially about NASA's constraints.
- Explaining the reasons for some of NASA's protocols, which may be necessary to NASA staffers but not understood by industry executives.
- Acknowledging cultural differences between government and industry and addressing them in initial meetings with partners. Many industries are used to working with academia and government, and realize that there are cultural differences in the way the public sector works. If NASA demonstrates an understanding and respect for the industry partners' "culture," they are likely to be more accommodating of NASA's.

The economic downturn and resultant tightening of companies' purse strings further accentuate the importance of retaining existing partners and building upon that customer base. In fact, as long as these trying times continue, the CSCs may find it difficult to maintain existing partnerships and commitments, and may have to devote their marketing resources towards retaining partners rather than attracting new customers.

The Role of Headquarters

Of the four audience segments identified in the communication strategy, two are already regularly targeted by the CSCs and the Office of Space Product Development. These two offices regularly conduct industry-wide outreach through trade show exhibits and print materials. In addition, the CSCs regularly target specific industry scientists or workgroups to encourage their participation in microgravity research. Here we describe some ways in which outreach to these two audiences can be improved, but we believe that the resources at Headquarters Code U can be used most effectively in outreach to the two audiences that are currently being reached by CSC and SPD efforts to only a limited degree: (1) the influential public and (2) industry executives and leaders.

In our interviews with CSC and SPD staff, we repeatedly heard that attracting and engaging industry interest is difficult because the entire concept of microgravity research is new to industry. Furthermore, even when scientists and others who are close to the research are convinced of its utility, it is difficult to persuade senior executives to commit funds to this enterprise. CSC staff described a long (and expensive) process of “courting” industry partners, saying that it can take several visits and up to two years to finalize a partnership agreement.

The experience of the CSCs illustrates a basic fact of public communication: it is not a linear, one-shot event. Only in very special circumstances does one communication product—such as a brochure, advertisement, or article—motivate the desired action on the part of the target audience. More often, communication is an incremental process, whereby messages in various channels cumulatively influence the target audience’s actions. Thus, the context in which a particular message is received is critical to determining how the target audience member responds to it. For example, if a CEO receives a request to participate in microgravity research from a lead product development scientist, he/she is more likely to act on that request quickly if something about NASA’s program has already been seen in a business paper or magazine, and some sense of its potential value exists. A CEO is likely to be even more favorably disposed if it is known that another CEO in a similar field has benefited from it or if a chief competitor is considering a similar partnership.

By raising the profile of microgravity research and NASA’s efforts to advance microgravity research with industry partners, Headquarters’ efforts can greatly facilitate the work of the CSCs and SPD. If more people have heard of this effort and value it, it will be easier for the CSCs to engage corporate scientists, and in turn, for corporate scientists to get support from company decision makers. Similarly, a more favorable context will increase the likelihood that materials distributed at trade shows will be read and acted upon.

Timing the Communication Program

As mentioned earlier in this report, the economic downturn and the public’s preoccupation with issues of national security have (temporarily) relegated scientific research and exploration to the background. Private sector funds for basic research are likely to be tight. Furthermore, there has been some serious media criticism of NASA’s management of the ISS, and its fiscal and management procedures in general.[26, 27] In light of this unfavorable media environment, we recommend that, for now, NASA should focus more on building the credibility of the microgravity research program than on soliciting private sector funds. As the environment becomes more favorable, more explicit invitations to participate in the research can be woven into the media outreach.

Thus we have organized the media outreach program into two phases. The first will focus on more general informational messages about NASA's commercial microgravity research program and its scientific and commercial novelty and value. In the second phase, the outreach will include more mentions of specific partnership opportunities. While we have not timed these two phases, we expect the first phase to last for one to two years, depending upon the economic and media situation.

We strongly recommend that NASA use the "low-key" publicity of the first phase to improve customer service and prepare for more active interest from the private sector. Communication can drive industry interest, but it is the substance of the program and the value that NASA can generate that will decide whether the program will live or die in the long run.

Furthermore, if industry interest is disappointed once, it is even more difficult to generate it the second time around. In this regard the parable of the boy who cried wolf is applicable. If a strong communication campaign generates a number of calls that are not "fulfilled" for lack of programmatic support, NASA will find it exceedingly difficult to attract industry partners the "second time around." Thus, NASA's public communications in Phase 1 should focus on bringing this issue to the public's attention and generating support, but no strong calls to action should be sent out until NASA is equipped to handle the interest generated. The following section describes some of the steps that should be taken to increase NASA's ability to make optimal use of the industry interest generated through this communication program.

Preparatory Steps

We recommend that NASA take the following steps to support its commercial microgravity program and prepare for more active industry interest (see Table 10A). Many of these recommendations have already been made in prior reports and we will not belabor them, but we believe them to be important determinants of the success or failure of this program. Some of these recommendations involve procedural or programmatic changes at NASA; others concern channels to enhance NASA's internal communications and coordination among divisions and groups who communicate with external audiences about the ISS.

- Flight manifest procedures need improvement. The current procedures for flight approval are complex, cumbersome, and unpredictable. Wherever possible these procedures should be simplified and streamlined. These procedures should also be more consistent so that every new research payload will be manifested within the same timeframe. Most important of all, NASA must explain these procedures and timelines clearly to industry partners and deliver on them as well as it can. If unforeseen circumstances lead to changes in the schedule, these constraints should be clearly explained to partners.
- Fast-track flight procedures should be implemented. As noted above, science is an incremental endeavor. When an industry partner seeks to replicate a prior study it should be fast-tracked utilizing a simplified flight manifest procedure. This will facilitate replication and validation of studies, thereby contributing to the credibility of microgravity research as a scientific discipline.

- **Procedures for ensuring confidentiality of Intellectual Property should be clarified and communicated.** Given that most microgravity research is fundamental or very basic applied research, intellectual property rights did not appear to be as big an issue as we had expected. However, this issue will only become more important as microgravity research advances. Some interviewees also raised the issue of protecting the confidentiality of submissions to NASA, including their business plan and the composition of the materials and equipment being sent into space. NASA must make sure that the confidentiality of all the information presented is protected at all times and these procedures should be discussed with potential partners.
- **A single point of contact should be established.** Businesses interested in pursuing microgravity research should be able to contact a single person or office that will be knowledgeable about *all* the microgravity research being conducted at the various CSCs, and can guide the caller to the relevant CSC or scientific group. This contact person should be able to determine which CSC might be the best partner for an interested business and facilitate partnership development. The contact should also follow up with the industry member to see how the partnership is progressing, and should be charged with relationship management and customer satisfaction. Ideally this contact person should be reachable via a front-door mechanism such as a toll-free number.[10]
- **Agreement on communication strategies and messages/Development of a message platform.** Development of a comprehensive and consistent message platform is essential for communicating coherently with the public and the media. The first step in this is to generate confidence and buy-in from relevant senior staff members. We have proposed messages for each of four target audiences in this report, but these messages need to be developed further in collaboration with NASA so that key staff members are comfortable with them and invested in them. This can be accomplished via a half-day meeting with selected officials. Once a consensus is reached on the basic messages, these should be developed into a more detailed message platform that serves as a guideline for all materials and in training spokespersons. Furthermore, we recommend a series of strategy training sessions during which employees who prepare marketing materials regarding the ISS will be instructed in these messages and the basic strategic and tactical guidelines that should inform their work. Tool kits, samples, and other materials should also be distributed to these staffers to help them implement this strategy in their communications.
- **Identification and training of spokespersons.** Having a set of well-trained, charismatic spokespersons for this issue will greatly help in generating media coverage that presents NASA's case for microgravity research to the public. NASA thus needs to identify and train a set of spokespersons who will be available to speak with the public, industry audiences, and the media about the commercial space program and the value of the ISS as a research laboratory. Media training for these spokespersons will ensure that they consistently speak to NASA's message platform and present their case to have the desired impact. In this initial phase, we recommend that these spokespersons be drawn from NASA or the CSCs and the selection be based on the spokesperson's presentational skills rather than knowledge or position. As the program gains momentum, it may also be possible to identify influential

[10] We heard from many NASA sources that this central "front door" office has been established. However, it is clearly not operational because there was little consensus on which office or NASA official held this responsibility, what his/her job description was, and how others' jobs and tasks fit in with this. Some interviewees thought this "front door" office was housed at the Marshall Space Flight Center, others thought Headquarters (Code U) had this primary responsibility, and some believed this responsibility lay with the Johnson Space Center.

professionals from industry or academia, who can serve as spokespersons for this enterprise.

- **The CSC network should be strengthened.** Our research suggests that microgravity research is not currently advanced enough to warrant entrepreneurial offers from the target industries (although it is possible that some aerospace companies or others that wish to use the ISS as a test-bed can avail themselves of this procedure). For now, we believe that the CSCs are vital to NASA's commercialization efforts. Unfortunately the CSCs all too often work in isolation and with very limited funds. As with the conduct of any highly skilled endeavor, tacit knowledge is acquired that can be extremely beneficial to others. The sharing of this knowledge—gleaned from outreach, research, hardware development, and flight manifesting—could be highly beneficial to all CSCs. Moreover, the CSCs should be encouraged to collaborate on research and share findings so that microgravity research can be effectively advanced. NASA can provide the forums and the opportunities for such collaborations.

- **Links between NASA and the CSCs should be strengthened.** NASA should be more closely linked with the CSCs both in external and internal communications. However, this should be done without dampening the diversity and entrepreneurial spirit of the CSCs. One of their major strengths is that the CSCs can move swiftly, only minimally encumbered by NASA's bureaucracy. The closer links we suggest are not intended to bog the CSCs down but should stem from more bi-directional sharing of information (i.e., NASA must both give and take information from the CSCs) and should build the sense that the CSCs are part of a larger endeavor and are supported in their work.

  The annual meeting of CSC directors is an ideal forum for such a bi-directional flow of information. NASA can use this opportunity to convey to the CSCs their important role in NASA's strategic plan, clarify procedures and policies (and the reasons for them), and generally forge closer ties with the CSCs. This annual communication should be supplemented by regular email updates to keep the lines of communication open. CSCs should be encouraged to raise issues for debate and discussion. Rather than think of NASA as a reviewer and grant-maker, they should see it as a partner willing to guide and assist them.

  The CSCs should also be encouraged to leverage their association with NASA in their marketing efforts. While they sometimes play down their association with NASA (because their industry partners fear government bureaucracy and scrutiny), NASA can guide them in using this association to their advantage. Also, as NASA's commercial space program becomes better known (through outreach to the general public and industry audiences), the CSCs will see greater benefit in identifying themselves as part of this high-profile program.

- **A central fully searchable database of microgravity research findings and commercial microgravity efforts is needed.** Currently the on-line sourcebook presents the results of microgravity research conducted by the CSCs. Although this content is certainly very helpful it could be expanded to incorporate scientific microgravity research and be fully searchable by topic, research method, researchers, industry partner, CSC, etc. Having a central repository of scientific and marketing information will greatly facilitate communication and coordination among the CSCs and the different NASA officials engaged in promoting commercial microgravity research. It will also help inform communication efforts and materials developed by NASA and the CSCs for their various constituencies.

Table 10A: Implementation Plan for Communication Strategy, Preparatory Steps

Programmatic Recommendations

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Streamline payload approval processes	Ongoing	NASA	
Clarify payload manifestation priorities	Develop a consistent set of regulations and priorities, preferably in collaboration with the CSCs. Reach agreement on ways to communicate these to industry partners.	NASA/CSCs	

Communication Oriented Recommendations

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Central 'front door'	NASA should set up a central point of contact to receive and direct industry inquiries to appropriate people. The role and responsibilities of this office should be clearly defined in relation to other offices engaged in promoting space research and product development.	NASA	
Message platform development	The contractor will hold a half-day meeting with NASA executive team to review and finalize the core campaign messages. They will then develop a message document with messages and factual backup to support those messages, and a Q&A document (which addresses common questions that reporters are likely to ask spokespersons).	Contractor	NASA will identify all relevant staff members who need to be involved in developing messages for the commercial microgravity program. Up-front agreement on messages will avoid controversy and ensure consistency when the program is implemented.
Marketing Training	The contractor will conduct four training sessions with NASA staffers who are involved in marketing the ISS. These sessions will present basic guidelines for ISS marketing, key messages, and recommended strategies and tactics. The contractor will prepare the course curriculum, a communication guidebook and a toolkit for attendees. These materials will enable them to use this information easily and to train their own staff members in these messages and communication techniques. The contractor will also be available to consult with NASA staffers about specific tactics or strategies that they may choose to implement or specific challenges that they face.	Contractor	NASA will identify relevant staff that should be trained. One possibility is to hold one session each at Headquarters, MSFC, JSC and KSC.
Spokesperson training	The contractor will train four NASA staffers to be spokespersons for this issue. They will be trained to deliver the messages at the appropriate level of detail and to field questions and comments.	Contractor	NASA will identify appropriate spokespersons.

Table 10B: Implementation Plan for Communication Strategy, Phases 1 and 2 for Influential Public

Phase 1

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Media kit	This estimate is for the basic components of a media kit, which would include a fact sheet on the ISS and NASA, a press release, positive news articles (if available), bios, contact information for spokespeople, camera-ready artwork, and other background materials that will facilitate reporting on this issue.	Contractor	The basic information for this kit is already available at NASA's website and through existing materials. The contractor would need to compile these materials into a common format consistent with the message platform.
Press conference	The contractor will organize one large press conference to "introduce" microgravity research to the press. Contractor will be responsible for ensuring appropriate media attendance through media pitches and appropriate story angles.	Contractor	Key NASA staffers and spokespersons would attend this conference.
Press releases and media pitches	The contractor will develop and pitch stories to generate media coverage around the topic of microgravity research. This could include joint publicity with corporate partners who sponsored the research.	Contractor	NASA staffers who are listed as contact persons may have to take journalists' calls.
Background briefings	The contractor will arrange briefings for business and science journalists at the top five national newspapers. (*The Washington Post, The Wall Street Journal, The New York Times, USA Today* and *Los Angeles Times*.) These will be detailed discussions on background, current research and the future of the commercial microgravity research program to get these reporters interested in the issue and to educate them about it. This is an intensive, relationship-building exercise with the goal of garnering at least one and perhaps two major feature articles in these papers.	Contractor	Although the contractor can handle this, it may be useful to have one NASA spokesperson present at these background briefings.

Phase 2:

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Press conference	A second press conference will be conducted at the start of the second phase of the campaign. Based on the progress of the last phase and the altered media environment,, this conference would have a different theme than the first, e.g., to celebrate research progress and/or formally invite commercial investment in space.	Contractor	NASA staff participation.
Press releases + pitching	As in the last phase, the contractor would generate media coverage for at least two major microgravity research findings in the popular press.	Contractor	None.

Table 10C: Implementation Plan for Communication Strategy, Phases 1 and 2 for Industry Executives and Leaders

Phase 1

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
CEO briefings	The contractor will arrange a series of one-on-one and group breakfast briefings in five target markets with 20 CEOs. This will include identifying appropriate CEOs, developing tailored information kits, organizing meetings (e.g., venue, food, etc.), securing industry executives' attendance at these meetings, developing the agenda and content of the meetings, attending these meetings, and follow-up, as appropriate.	Contractor	Key NASA officials and spokespersons would have to attend these breakfast meetings.
Article placements	The contractor will place articles and stories in in-flight and Ivy League alumni magazines such as *Hemispheres* (United Airlines), *American Way* (American Airlines), *Sky Magazine* (Delta), *Princeton Alumni Weekly, Harvard Magazine, Stanford Magazine,* and *Yale Alumni Magazine,* that are commonly read by business executives. Story angles could include business breakthroughs resulting from the ISS, and how businesses are looking to space to identify science breakthroughs. This estimate is for pitching 10 such magazines.	Contractor	None.

Phase 2

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Leadership panel	Hold a half-day session with business leaders who have agreed to join or contribute to an industry panel to guide the commercialization process. The contractor will: prepare agenda, lay out consortium goals and objectives, provide information kit, elicit support from appropriate business executives, and identify means of ongoing communications for consortium members.	Contractor	Participation of higher-level NASA staff will be required.

Table 10D: Implementation Plan for Communication Strategy, Phases 1 and 2 for Industry

Phase 1

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Conference/trade show presentations	Ongoing	NASA & CSCs	
Turnkey tool kit & slip sheets	The contractor will develop a kit that can be customized with specific slip-sheets for each industry audience.	Contractor	None.
Speaking opportunities	Opportunities for spokesperson to present at industry meeting and events should be developed.	NASA & CSCs	
Contact follow-up	Contacts generated via trade shows and other outreach should be catalogued. Follow-up is key, e.g. through an email newsletter, or phone conversations with a NASA staffer who can evaluate the "client's" needs and match them to relevant CSC projects.	NASA	
Partnership development	Partnerships with industry and trade organization should be fostered.	NASA	
Microgravity Research Database and electronic news update	As industry becomes familiar with microgravity research, interested industry partners and potential partners can be given access to a microgravity research database. This site may have some tailored pages for specific industries. An electronic news update to keep potential partners informed of new findings that interest them will keep them engaged in this research.	NASA	

Phase 2

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Conference/trade show presentations	Ongoing	NASA & CSCs	
Turnkey tool kit & slip sheets	Updated	Contractor	None.
Speaking opportunities	Ongoing	NASA & CSCs	
Contact follow-up	Ongoing	NASA/Contractor	
Partnership development	Ongoing	NASA	
Microgravity Research Database and electronic news update	Ongoing and expanded		
Media interviews	Contractor will develop story angles and conduct ongoing pitching to targeted trade publications to reach audiences in the target industries. Examples: *Scientist, Biotechnology Focus, Biotech Magazine* and *Drug Topics.*	Contractor	NASA spokespersons must be available for interviews.
Trade press advertisements	Contractor will work with NASA to develop an advertising and placement strategy.	Contractor	

Table 10E: Implementation Plan for Communication Strategy, Phases 1 and 2 for Corporate Scientists

Phase 1

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Microgravity publications	Ongoing. Expand readership. Add electronic news update as a way to inform people about new findings in the area.	NASA/CSC scientists	
Research presentations	Ongoing	NASA/CSC scientists	
Scientist briefings	Ongoing	NASA/CSC scientists	
Website and database of microgravity research findings	Web-accessible database containing information on programs of study as well as contact information for lead scientists. All published papers on the topic should be posted on this site.	NASA	
Electronic News Update	An electronic news update with microgravity research findings should be published periodically to report on new projects and findings in the microgravity field. This news update should be simple, brief and industry-focused, with links to more detailed information on the Web.	NASA	CSCs to provide information regularly
Direct mail	Direct mail pieces should be developed and sent to specific corporate laboratories.	CSCs	A contractor can assist in identifying appropriate corporate work groups and developing these materials.

Phase 2

Tactics	Description/Ideas	Primary Responsibility	Support Needed from NASA/CSCs
Microgravity publications	Ongoing	NASA/CSC scientists	
Research presentations	Ongoing	NASA/CSC scientists	
Scientist briefings	Ongoing	NASA/CSC scientists	
Website and database of microgravity research findings	Updated on an ongoing basis.	NASA	
Newsletter	Ongoing. Readership should be expanded.	NASA	CSCs to provide information regularly.
Direct mail	Direct mail pieces should be developed and sent to specific corporate laboratories.	CSCs	A contractor can assist in identifying appropriate corporate work groups and developing these materials.
Microgravity research panel	A select group of corporate microgravity research scientists should be instituted to be spokespersons for microgravity research in their industries.	NASA (with contractor as needed).	

The Communication Program

Table 10 on pages 78-82 lays out a recommended communication program, organized into two implementation phases. This table shows specific communication activities for each of the four target audiences. These are briefly described and elaborated in the next few sections.

We understand that NASA and the CSCs already conduct some of these recommended activities. This plan is intended to build on existing activities and efforts, not to start fresh with an entirely different set of tactics. Many of NASA's current activities are effective; however, we do present ways to improve and streamline some of these communication activities.

The Influential Public

This audience consists of the educated and professional lay public, mostly between the ages of 30-65, and particularly those who are oriented towards technological advances and may be considered opinion leaders in this area. Three objectives drive the communication with the influential public:

- To increase awareness and perceived relevance of space-based research, particularly aboard the ISS.
- To increase awareness and perceived relevance of NASA's technical and research expertise, particularly outside of space exploration.
- To generate awareness of space commerce and a NASA partnership opportunity—discussion and engagement in the topic.

Tactical Considerations

- The key program-shaping factor for this audience is that the public currently has little or no awareness and knowledge of microgravity research, its benefits and its applications. Also, although a substantial proportion of the public knows that the ISS exists, they lack knowledge about why the ISS exists, what it can do, and what is currently occurring on station.
- On the positive side, the public does have high regard for space exploration. National pride in NASA and its accomplishments is very high. Most Americans want the U.S. to remain the leader in space exploration and are quite supportive of this effort. Although this support for NASA funding has declined and will probably continue to decline in the current economic environment, this program should leverage the public's pride in NASA and its legacy of accomplishment and excellence.
- The goal of the program is to renew and extend this pride. NASA is known for its accomplishments in space exploration; the objective of the communication directed to this audience should be to emphasize how NASA has contributed to scientific advances that affect people's lives on Earth.
- The value of space research should also be emphasized.[11] The goal is for people to understand how this research will yield findings that can change their lives. The tone of this communication should be more inspirational than informational, and care should be taken to not lose the main ideas in scientific detail or terminology.
- Findings that lead to consumer-oriented products and services should be promoted to the general public. Advances in health and medicine are generally of interest to the public, as are related issues such as safety and environmental sustainability.
- Positioning the commercial microgravity research effort as a "coming together" of business, government, and academia to "solve problems" will also help earn the public's interest and support.

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[11] In communication with the public the more understandable term "space research" is preferable to the more technical term "microgravity research," although both may be used.

Specific Tactics

- As shown in Table 10B, much of the communication program for this target audience focuses on generating media coverage for NASA's microgravity program in mainstream business and mass publications (such as *Business Week* or *The New York Times*) as well as targeted science and technology publications (such as *Discover* or *Wired*). Some ideas for generating such coverage include:
  - Conducting press conferences about microgravity research around shuttle launches when the press is already available and tuned to space-related issues such as promoting a thematic launch or promoting activities by the industry panel. As mentioned earlier, due to the fact that shuttle launches and their research load are a routine occurrence, they do not command as much media attention as they used to. Thus, this activity involves generating innovative story angles to attract the press to this topic.
  - Conducting publicity jointly with corporate partners and/or members of the industry leader consortium (as described in the next section).
  - Presenting targeted pitches and editorial briefings to select media sources, i.e. specific papers and journalists that deal in forward-thinking science issues.
  - Preparing informational materials containing story ideas for reporters.
  - Preparing and distributing catchy newsbytes as snapshots or capsules to be included in mainstream papers such as *USA Today*.

A Note on the Implementation of Recommended Media Activities

Like all Federal agencies, NASA has a public affairs office to manage communication with the media. This office is very experienced in presenting NASA to the public by communicating with the media or through other direct means (e.g., World Wide Web). However, government agencies often also contract with communication, advertising, marketing or public relations agencies to promote specific products or activities through earned[12] or paid media. This kind of coverage is distinct from the overall media relations function for the government agency; while government agencies are not allowed to promote themselves via the media, they are permitted to promote specific opportunities, practices, behaviors, or services that may benefit the public. Furthermore, these communications are often driven by message themes rather than by news and events.

Some examples of such programs are:

- The National Cancer Institute uses a communications agency to promote behaviors such as regular cancer screening to the public and to health care providers. This is achieved via public service announcements, collateral materials, as well as articles and stories in the mainstream and specialty media.
- The Agency for Healthcare Research and Quality uses a communications firm to generate media coverage around specific clinical guidelines to increase their adoption by healthcare providers.
- The Bureau of the Census used an advertising agency to rejuvenate its image and to promote strong minority participation in the 2000 census.
- Centers for Disease Control and Prevention regularly launch communication campaigns to raise the profile of specific illnesses and to promote good screening and disease management practices.

In all cases where an external firm is hired to promote an issue or activity for a Federal agency, their work is tightly monitored by project officers at the Federal agency to ensure that it is accurate and consistent with the guidelines and principles to which government agencies must adhere. In many cases, however, experienced contractors come to learn the issues and stylistic preferences of their clients, and, through their accumulated experience, may actually be better informed than their clients about the boundaries within which government agencies must operate. There are at least two advantages to hiring an external contractor to generate media coverage:

1. Contractors are less entrenched in the "world" of the government agency and can make better judgments about how a story can be presented in a newsworthy way (from a lay or media person's perspective).
2. Most government public affairs offices are busy dealing with the "everyday" work of communicating about the agency and have little time or interest in taking on these "special projects" and promoting them proactively and intensively. This work is better left to a dedicated team.

NASA already contracts out some of its public relations work, albeit on a small scale and for secondary markets and publications. We believe that media outreach for the ISS should also be contracted out to an external communication firm because (1) it promotes a specific activity or program rather than the overall functioning of NASA itself, and (2) it requires a highly pro-active and intensive approach, (3) it has a strong educational component, and (4) it should be driven by message themes rather than news and events. The main goal of this communication is not to "promote" or "represent" NASA but to educate the public regarding the new frontier of space research and the concept of public-private-academic partnerships to explore this frontier.

[12] Earned media refers to public service announcements, news and/or feature stories, clips or articles and other kinds of media presence that is not paid for by the sponsor.

We see this as a very specific and concentrated outreach effort or “campaign” to educate the press, spark its interest in space research, and to actively position space research with the media and the public. After this initial work is done, the ongoing press activity to sustain the effort can be conducted by NASA.

Industry Executives and Leaders

This category includes CEOs, high-level executives, analysts, association heads, and others who are considered to be the thought leaders in their respective industry areas. Three objectives drive the communication with industry executives and leaders:

- Engage senior executives and industry leaders to participate in and guide NASA’s commercialization venture.
- Encourage senior executives and industry leaders to promote space commerce to media and within their industry.
- Encourage senior executives to take the lead on commercial space research for their sector.

Tactical Considerations

- Most industry leaders are driven by short-term bottom-line concerns, but like to think of themselves as visionaries who take a longer-term perspective. Thus, both the long-term and short-term benefits of microgravity research can be pitched to this audience. This audience is likely to be excited by the long-term potential of microgravity research.
- Although microgravity research is unlikely to provide short-term return on investment, it does provide many intangibles such as prestige, leadership, and publicity. These should be communicated subtly and indirectly, for example through press coverage for events attended by these leaders and at other opportunities for joint publicity with NASA.
- The minimal cost of participation should be emphasized. Executives may be primarily interested in how much microgravity research will cost. The ability to leverage cost with the CSCs and with NASA must be stressed as a result.

Specific Tactics

- The main programmatic recommendation for Phase 1 is to conduct a series of breakfast briefings in select markets with select industry CEOs (see Table 10C).[13]
- This will be supported by placing articles on the possibilities of space commerce (from a business perspective) in targeted media such as in-flight magazines and Ivy League alumni publications

[13] We envision a small gathering (roughly 20 executives) that allows for a high level of participation by attendees. We have found that this kind of selective and intimate gathering can successfully foster relationships and generate commitment among participants. We have had good success utilizing a similar format with such clients as the Bureau of Transportation Statistics and Emergency Medical Services.

- As industry interest develops, in Phase 2 it will become possible to convene an industry panel that will take a leadership role in shaping NASA's space commercialization venture. Just as NASA already engages corporate scientists on its research committees to identify the best research directions, it should now engage business leaders to guide the business and logistical aspects of its commercial space program. This industry panel could meet periodically to discuss ways in which space commerce can be facilitated. For this industry panel, NASA should:
  - Provide perks of membership such as interaction with astronauts, high-level scientists, launch passes, etc.
  - Generate speaking opportunities at venues that appeal to opinion leaders.
  - Create regular reports and other informational materials to keep them engaged.
  - Provide a "tool-kit" of messages and promotional materials that can be used by their organizations to generate publicity.
- In Phase 2 of the program, we also recommend conducting a series of briefings with respected analysts and writers for the target industries, as well as heads of influential industry associations. Educating these professionals about the opportunity offered by NASA as well as the "new frontier" of microgravity is likely to lead to favorable comments in their columns and speeches.

Industry-level Outreach

The objectives driving this broad-spectrum industry-wide communication effort are:

- Increase awareness of microgravity research applications for each industry sector.
- Increase perceived value of research partnership with NASA.
- Identify appropriate contacts for follow-up.

Tactical Considerations

- Although microgravity research provides few *immediate* breakthrough solutions for industry's technological problems, it does hold very great promise for doing so. Thus, outreach to industry should focus both on the long-term benefits of engaging in microgravity research and the short-term value of scientific discovery and innovation. The focus should be on publicizing relevant findings and the leads they offer for further research.
- Cost and expertise leveraging with NASA and academia should also be promoted. The central message should be that industries can explore the benefits of this research at little cost. Some of these benefits may be dramatic, and some may lead to incremental improvements, but all of them are worth exploring at this minimal cost.
- Relevance to the industry sector is critical for effective communication. Materials designed for a particular sector should discuss *all* the ways that sector can benefit from microgravity research (e.g., combining applications from different CSCs), without diluting the message with unrelated research. For example, publicizing the development of an unrelated new product—such as the Zen fragrance—to the metals and metal products industry merely dilutes the impact of the message. The communication should be about how NASA can contribute to a *specific industry* and not about *all* that NASA's microgravity research program has accomplished.

- The tone and style of industry materials should mirror the norm for that industry. For example, the biotech industry pictures itself as flashy, fun, and cutting-edge, so the materials should convey that look and feel. In contrast, the metal industry is relatively low-key; materials that are too flashy might not be given serious consideration.

Specific Tactics

Much of the industry-level outreach is being performed by the CSCs in conjunction with the Office of Space Product Development. We recommend continuing this outreach via these two offices. The suggestions below are designed to increase the effectiveness of their outreach efforts (see Table 10D):

- Currently SPD and the CSCs tend to organize their materials by individual CSCs and the research they conduct, rather than by industry audiences that might be interested in these materials. For example, the SPD website—although containing a great deal of information—is not tailored toward specific industries and does not explain how particular industries can benefit from microgravity research. This makes it harder for an industry executive or scientist to determine whether microgravity might be beneficial for his/her organization to pursue. This industry-specific focus should be present in all outreach materials, including brochures, websites, and tradeshow presentations/booths.

  We have therefore recommended that NASA develop industry-specific materials (brochures, exhibits, etc.) for at least two or three main groups of target industries. For example, NASA could develop one set of materials for biotech and agritech, a second for the electronics and optics industry, and a third for the metals, transportation, and heavy machinery sectors. As a start, in Phase 1, we recommend developing a customizable turn-key kit that can be used for marketing to various industries. These can be distributed at trade shows and other conferences. We understand that the Office of Space Product Development has already begun to develop compilations of research that might be relevant to a particular industry sector. These pamphlets can be included in the turn-key information kit, along with information such as what companies in that sector are working with NASA, industry-relevant experience of NASA or CSC staff scientists, presentations that NASA staff may have made at that industry's conferences or meetings, and relevant press releases (e.g., about partnerships that NASA may have entered into with relevant industry organizations). The design and content of these kits will be geared to inspire confidence in NASA's commitment to, engagement with, and impact on that target industry.

- Several of the CSCs are likely to be conducting research relevant to a specific industry sector. Thus, industry-specific materials should feature a central "front door" contact number (such as 1-800-FLY-NASA) which puts an interested industry staffer in touch with someone who understands all the microgravity applications relevant to that industry sector, can help the industry "client" figure out what kinds of research are relevant to their needs, and then put them in touch with the appropriate CSCs. Callers should also be given the option to receive NASA's periodic electronic news update and/or newsletter to help them "keep an eye" on this field.

- In keeping with a more centralized, audience-focused approach, there should be systematic follow-up of contacts that were referred to the CSCs to see if they received the information they needed and to provide any additional direction or support. A database of contacts should be maintained. If possible, this central office should monitor which of the contacts led to research partnerships, which did not, and why. This information will be invaluable in refining communication as well as policies and procedures.

- Conference and trade show exhibits should be supplemented by speaking opportunities at these events. NASA should work with the CSCs to create conference presentations and symposiums to discuss industry-specific research findings and future research directions. These symposiums should combine relevant research and expertise from all the CSCs for a more unified and comprehensive presentation. While it is the CSC scientists who are in the best position to identify appropriate speaking opportunities, having NASA Headquarters or the Office of Space Product Development serve as a coordinator and facilitator of these presentations may help NASA get better overall coverage without duplication. NASA can also use some of its partnerships to generate more speaking opportunities for commercial or CSC scientists who conduct microgravity research.

- NASA should develop partnerships with professional and trade associations and organizations in the primary target industries to reach their members more effectively.
- To facilitate communication with industry sectors, NASA should develop a database of microgravity research findings relevant to each industry sector.
- The same "inside-out" focus is apparent in NASA's quarterly publication *Space Research* (and *Microgravity News* before that). This publication appears to be written for an audience that is tuned to NASA's world – its functioning, its grant mechanisms, its leaders, and its conferences. It is attractively designed and does a good job of reaching that audience. To reach a more peripheral audience that is less engaged with NASA, we recommend supplementing *Space Research* with a periodic, electronic news update. This publication should be brief (no more than a paragraph on each new project), but should contain links to more detailed reports and contact information for project directors (e.g., to the microgravity database mentioned above). It should focus on giving readers a flavor of the latest microgravity research and findings and alert them to possible opportunities that might relate to their work.
- As the program progresses (in Phase 2), NASA should place articles as well as advertisements in the trade press for target industries. The articles should discuss program successes as well as profile companies that have benefited from the partnership with NASA.

Corporate Scientists

Three objectives drive our communication to corporate scientists:

- To introduce microgravity research to appropriate scientists, thereby generating interest in this research.
- To increase credibility and perceived applicability of this research and engage scientists in a discussion of the possibilities for this research.
- To persuade scientists to suggest this research for their company or support this research in discussions with other scientists or managers.

Tactical Considerations

- Materials should employ fact-based appeals. Scientists are highly rational thinkers who need proof before they'll take a particular course of action. Fact-based appeals that focus on actual results and avoid over-hyping microgravity are likely to work best for this audience. These messages also will be largely informative rather than persuasive, and will be designed to build the stature and visibility of the discipline of microgravity research.
- This communication needs to be largely based on peer-to-peer interaction and is therefore best conducted by the CSCs.

Specific Tactics

- The best way to attract the attention of scientists is to present the results of microgravity research in trade and peer-reviewed publications. CSC scientists are already doing this as time allows, and this should be encouraged (see Table 10E).
- Scientists should also be encouraged to participate in symposiums or to present their studies at conferences and trade shows. As for the general outreach to industry, scientists from different CSCs may join to present related studies in a more comprehensive and impactful way.
- Briefings to scientists in selected industries, either one-on-one or to groups, should be presented. Although this is already being done by the CSCs, they can be more systematic in their selection of companies to which the work should be presented. The CSCs can also be more systematic in

following up on potential leads and referring potential partners to other CSCs if that is more appropriate.

- NASA should develop a website for scientists that includes a database of microgravity findings, peer-reviewed papers on microgravity, and applications of microgravity research. This collection of findings should be easily accessible to scientists. Contact information for lead scientists on specific research programs should also be included and questions and comments should be invited.
- In addition to *Space Research*, NASA's quarterly newsletter, develop an electronic news update for scientists that provides quick and timely information on microgravity research opportunities and findings. This newsletter should be brief but should contain links to more detailed reports and to contact information for the project directors. Alternatively, NASA could also maintain a detailed on-line database and send scientists email alerts whenever new information is posted to that site.
- Develop a select group of microgravity researchers that are invited to briefings, given updates on website developments, receive newsletters, etc.

Program Evaluation

Program evaluation typically has two components: (1) Process evaluation to see if the program is being implemented as planned, and (2) Outcome evaluation to see if the program is having the desired effect on the target audiences. As these descriptions suggest, process evaluation is an evaluation of program implementation, while outcome evaluation assesses both the effectiveness of the program strategy and the thoroughness with which it was implemented.

Relevant process evaluation measures for this program are:

- Monitoring media coverage of NASA's commercial research program.
- Monitoring media coverage of microgravity research.
- Monitoring conference presentations and panel discussions on microgravity research.
- Monitoring trade show exhibits.
- Attendance at CEO breakfast briefings.

Outcome evaluation measures relate back to the objectives of the communication. The communication objectives for this program are as follows:

- Widen awareness and perceived relevance of microgravity research among public and industry audiences.
- Create a public and media environment that values industry participation in this venture.
- Associate industry participation with valued attributes such as innovation and leadership.
- Position NASA's offer to highlight benefits while minimizing costs.

The first and second objectives relate to increased awareness of microgravity research, an increased appreciation for the benefits and relevance of this research, and increased positive image of companies that participate in this research. This can be assessed through periodic omnibus surveys, an inexpensive way to monitor public opinion. Omnibus surveys are standard phone surveys of nationally representative samples (usually about 1000 people) that are fielded once or twice a week by large market research companies. Individual companies and organizations can submit questions for the survey questionnaire at a minimal cost (roughly $500-$750 a question). By distributing the cost of fielding the survey among various organizations, the cost to each individual organization is minimized.

The third and fourth objectives relate to increased awareness and appreciation of NASA's commercial research program, not only among the public, but more so among those who work in the target industries. One way to assess this is to participate in specialty omnibus surveys of companies in specific industry sectors. However, these are much more infrequent and expensive than omnibus surveys conducted with the public. A more cost-effective way to obtain this information or at least roughly estimate it is to poll a random sample of people at industry shows and exhibits. If the program is working as planned, more industry personnel will be aware of the opportunity to partner with NASA.

In addition, movement on these objectives can be assessed by:

1. monitoring hits to NASA's website for commercial space research; and
2. setting up a central number to provide more information on this topic and monitoring calls to the number.

The number of calls and hits are both good indices of the interest generated in this topic. These can be further tabulated by industry sector, size of company, etc., to give a better sense of who is being reached and where efforts should be directed.

We hope to see other effects, too. The goal of the public and Industry Leader communications is to raise the visibility of this program so that a company can enhance its leadership status by investing in this research. We therefore expect that this program will make it easier and quicker for the CSCs to get companies to agree to invest in microgravity research, thereby shortening the "courtship period." Furthermore, they will be willing to invest more in publicizing their participation, thus starting a positive cycle by which publicity by specific participating companies itself promotes the overall visibility of the program and its benefits. We also hope that implementing some of the recommended changes will make it easier for NASA to develop contacts and build fruitful relationships with industry partners, industry analysts and writers, and the media. However, many of these behavioral changes are contingent upon NASA having adequate procedures and systems to convert industry interest into successful industry partnerships.

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